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POLY-PLUS DEVELOPMENT PROGRAM.(U)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A compilation of five reports concerning the application of scrim to polyethylene film in order to create a lightweight gas barrier to be used in fabricating balloons for lifting very heavy payloads into the stratosphere for scientific purposes.

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FINAL REPORT

POLY-PLUS DEVELOPMENT PROGRAM

Office of Naval Research Contract N00014-72-C-0494
NR 211-164

The following five reports have been compiled within the Office of Naval Research to fulfill the contractual requirements and to insure the availability of technical data resulting from Department of Defense sponsored research. The development of POLY-PLUS material and fabrication techniques has not yet resulted in a usable heavy-load balloon system. Nevertheless, the knowledge gained through fabrication techniques attempted in this effort have influenced the state of the art of design of both the "natural shape" and "super-pressure" high altitude scientific balloons.

Reports concerning different aspects of the program reside at the National Scientific Ballooning Facility, Palestine, Texas, and Sheldahl Company, Northfield, Minnesota.

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CENTRE NATIONAL D'ETUDE SPATIALES

CENTRE SPATIAL DE TOULOUSE

DIVISION "SYSTEMES ET PROJETS BALLONS"

Poly +

CC: J. Munson

MAIN PROPERTIES AND SEAL FEASABILITY

OF POLY +. BALLOON MATERIAL

(POLYETHYLENE FILM - POLYESTER YARN - COMPOSITE.)

Contents

Enclosures : 3 tapes samples
5 edging samples
6 seal samples
1 cylinder specimen

L'Ingénieur responsable

Fouchard

P. FOUCHARD

Le Chef du Département "VEHICULES"

R. REGIPA

I. - INTRODUCTION

The purpose of this short study is a first investigation of Poly + seal feasability using CNES techniques, with providing testing specimens in a cylindrical form.

Using a special device fabricated by the GT Schjeldahl Cy, these specimens will be tested to look for tensile and shear strength capabilities under various loads.

For seals definition and characterization a series of tests have been conducted on the candidate material and on different seal specimens.

2. - DESCRIPTION OF FILM SAMPLES :

Two samples of Poly + were forwarded to the CNES by the NCAR (pieces 1.10 m wide and about 3 m long) - this material is composed of 20 μ Polyethylene and Polyester grid : 1.6 yarn/cm in the machine direction (MD) intersecting 1 yarn/cm at approximately 63° (DD) with the MD yarns.
(weight : 33 g/m2).

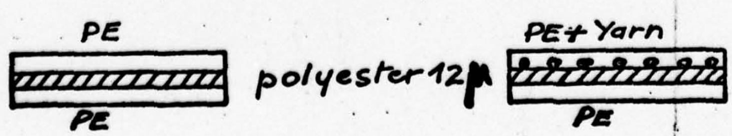
3. - CNES SEALING TECHNIQUES :

- Seal (and reinforcement) of strato balloons gores is based on the use of strength and heat sealable material, called " TRIPLEX ". They are tapes (25 mm - 1" wide) made of :

For strength : 12 μ Terphane polyester film (Mylar)
For strength and untearability : 12 μ Terphane + grid :

- 2 or 1 yarns/cm in both directions MD and TD, called G (2x2) or G (1x1)
- Tri-axial grid (2 yarns/cm MD - 1 yarn/cm 82° DD)

For sealability : Polyethylene or other sealable coating. (10 to 20 μ)



.../...

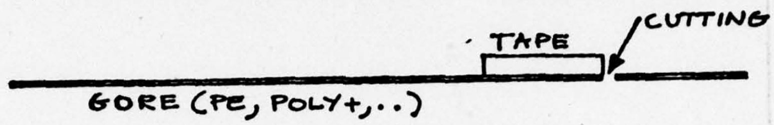
In the following tests we retained :

Triplex 20.12.20 (PE 20 - Terphane 12 - PE 20)
10.12.10 (PE 10 - -"- " - PE 10)
Scrim Triplex 10.12.G (2x2).10 (PE 10 - T12 - Yarn - PE 10)

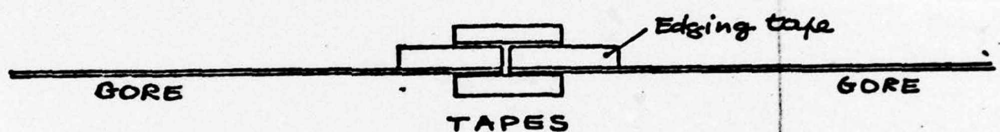
GT 300 (1/2-1/2) ordered to GT Schjeldahl U.K.

- The sealing technique is the following :

1. - Edging and cutting of the gore.



2. - Edge to edge sealing with overlapped tapes.



* Edging corresponds to a "soft" seal to avoid stresses concentrations when the base film reaches the edging tape.

* Overlapping corresponds to a "strong" seal.

* In these operations, tapes are used as a heat quantity transfert strip.

4. - SEALING OPERATIONS :

Within the samples dimensions, we have not used strato balloons equipments. All the sealing operations have been made with a machine specially used for spherical Ø 0.50 to 1 m. balloons manufacturing.

Heat rolls of this device are not working in the way of strato balloons machines (Seal temperatures were between 130°C and 140°C) - Temperature acquisition is not so accurate). Cutting operation has been handly made.

.../...

4.1. - Edging specimens

We provide several samples :

	sample nb (* unsupplied)
• Edging (PE side) Poly + applied to 20.12.20 tape	I. 1
" " " " " 10.12.10 "	I. 2
" " " " " 10.12.G (2x2).10 tape	I. 3
• Edging (grid side) Poly + applied to GT 300 tape	I. 4
" " " " " " 20.12.20 "	I. 5 *
" " " " " " 10.12.10 "	I. 6 *

We met any problem for this operation, only with the "Edging Poly + (grid size) with Triplex tape".

In this case, the peeling strength is very weak : presence of adhesive, confirmed by the high quality seal of GT 300 applied to this side of the Poly + :

4.2. - Peeling specimens : a strip of 25 mm wide - MD Poly + sealed on different tapes.

• (PE side) Poly + applied to 20.12.20 tape	II. 1 *
" " " " 10.12.10 "	II. 2 *
• (Grid side) Poly + applied to 20.12.20 "	II. 3 *
" " " " " 10.12.10 "	II. 4 *
" " " " " GT 300 "	II. 5 *

4.3. - Sealing specimens :

The edge to edge sealing operations with overlapped tapes have been made in the following way :

Edging	Side	Sealing	Sample nb
MD and TD - 20.12.20 tape	Poly	2 2 (20.12.20) tapes	III. 1
TD - 10.12.10 tape	Poly	2 2 (10.12.10) tapes	III. 2
MD and TD - 10.12.10 tape	Poly	2 (10.12.10) tapes (1)	III. 3
MD and TD - 20.12.20 tape	Poly	2 (20.12.20) tapes (1)	III. 4
TD - 10.12.10 tape	Poly	10.12.10 tape GT 300 tape - grid side	III. 5
TD - GT 300 tape	Grid	10.12.10 tape - Poly GT 300 tape /side	III. 6

(1) sealing operation made on one of the strato balloon machines.

- We also manufacture seals with reinforced tapes (GT 300 or Triplex) but specimens are to small to be provided.

- Edging in the TD direction have been done for tensile tests.

- All these operations were easily conducted, however we met some difficulties for a good position of the two films to be sealed edge to edge. We also saw that the quality of heat rolls coating was not good enough to avoid blocking effect on the outside poly of seal tapes (with no influence on mechanical characteristics) - These two factors will not be on strato balloons equipments.

5. - TESTS AND RESULTS :

Within delay problems, we had to limit tests. We looked only for mechanical characteristics mainly at ambient temperature.

5.1. - Peeling tests

Experiment :. 25 mm wide tape sealed on the poly + (MD).
. tests on the Instron machine at 21° C.
. 10 mm/mn strain speed - 80 mm peeling length.

Tests results on table 1 - Typical curve Fig. 1

Peeling strength of Poly + on to either Triplex - Poly side either GT 300 - grid side is nearly the same. It is of a very good quality. In each case we noticed that PE of the Poly + stays on the tape after peeling.

For the peeling strength of Triplex on to the grid side, we recorded very low values. It is too early to conclude on the definitive reject of Triplex tape edging and sealing on to Poly + (grid side) because :

- limited number of tests
- unknowledge of Poly + manufacturing (presence of adhesive)
- and however good quality of shear strength (on Instron machine - uniaxial test) of the seal with Triplex on the grid side Poly +.

.../...

5.2. - Uniaxial tensile tests (Machine direction)

Uniaxial tensile tests have been done on the different seals (across the seal direction) and on the base film Poly + for reference.

At ambient temperature + 21° C

- Each value is the average of n specimens defined on table 2.
- 25 mm wide - 100 mm long specimens.

We record : F_M , max tensile strength Kg/cm

A , elongation (max strength) %
(50 mm/mn strain speed)

E , elasticity modulus (1% strain) g/cm
(2 mm/mn strain speed)

At low température - 60° C (limited tests)

F_M , Kg/cm

A , %

(10 mm/mn strain speed)

Test results (see table 2) - Typical curves Fig. 2.

Within limited number of tests, we must carefully conclude on the actual values recorded (peculiarly for modulus values). However for all these tests conducted on seals specimens each rupture was in the base film and never in the seal itself. Seal strength characteristics remains the same, compared to the base film Poly +. We never saw difference among the different tapes used for edging or sealing (Triplex or GT 300).

6. - CYLINDER SPECIMEN :

These first results conduct the manufacturing of the cylinder specimen (Ø 14" - 50" long) in the following way :

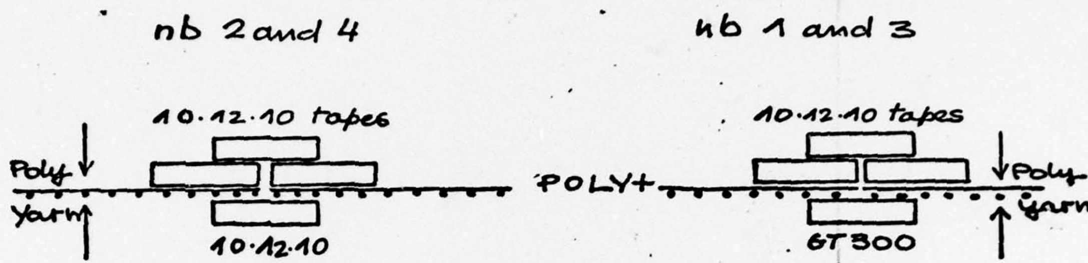
N.B - Preliminary tests and samples dimensions did not allow to realize more than one cylinder.

.../...

Two types of seal : edging with 10.12.10 tape and edge to edge sealing with overlapping tapes :

2 x (10.12.10) : seals nb 2 and 4

1 x (10.12.10) and 1 x (GT 300) applied to yarn : seals nb 1 and 3



7. - CONCLUSION

Seals have been done easily - the few difficulties we met will be moved away in using all the strato balloons devices (We work presently on a cutting device set up with the actual edging device for scrim materials) - The first results are very positive - It appears that our sealing techniques are fitted to the high quality material Poly +.

It remains to choose the tape for the edging of Poly + in the case where it will be necessary to edge the grid side.

Accurate conclusions will be done after cylinder tests and after works achieved on larger quantities.

-o-o-o-o-o-o-o-o-o-o-o-o-o-o-

TABLE 1 - PEELING TEST RESULTS 21° C

F g/cm (F_0, F_M, F_m, F_a, see Fig 1)

Description	Nb of specimens	$F_{O_{riginal}}$	F_{Max}	$F_{minimum}$	$F_{average}$
II. 1 (PE side) 20/12/20	2	100 .56 260 1.45	240 1.34 520 2.90	32 .18 30 .17	120 .67 140 .78
average		180 1.00	380 2.12	31 .175	130 .73
II. 3 (grid side) 20/12/20	2	< 10			
II. 5 (grid side) 300	2	250 1.4 310 1.72	270 1.51 250 1.40	80 .45 80 .45	160 .90 170 .95
average		280 1.57	260 1.45	80 .45	160 .92 .65

$$\frac{gm}{cm}\left(\frac{1\ lb}{454\ gm}\right)\left(\frac{2.54\ cm}{in}\right) = .0056\ \frac{lb}{in.}$$

TABLE 2 - UNIAXIAL TENSILE TEST RESULTS -

Description	T° C	nb of specimens	Machine Direction F_M Kg/cm max	Machine Direction A% Elong	nb of specimens	Machine Direction E g/cm (to be confirmed). max
Poly +	21°C	8	3,00 16.8	16,5	3	360 2.02
III.1	"	6	3,00 16.8	12	1	460 2.57
III.2	"	2	2,80 15.7	10,5	1	480 2.68
III.3	"	6	3,00 16.8	13	1	300 (?) 1.68
III.4	"	2	3,10 17.3	13,5	1	490 2.74
III.5	"	2	3,00 16.8	13	1	340 1.90
III.6	"	2	3,15 17.6	14,5	1	290 (?) 1.62
Poly +	-60° C	3	3,65 20.4	13	-	---
III.3	"	2	3,35 18.8	9	-	---
III.4	"	2	3,65 20.4	9,5	-	---

$\frac{kg}{cm} \cdot \frac{1000\ gm \cdot lb}{kg \cdot 454\ gm} \cdot \frac{2.54\ cm}{in} = 5.6\ \frac{lb}{in}$

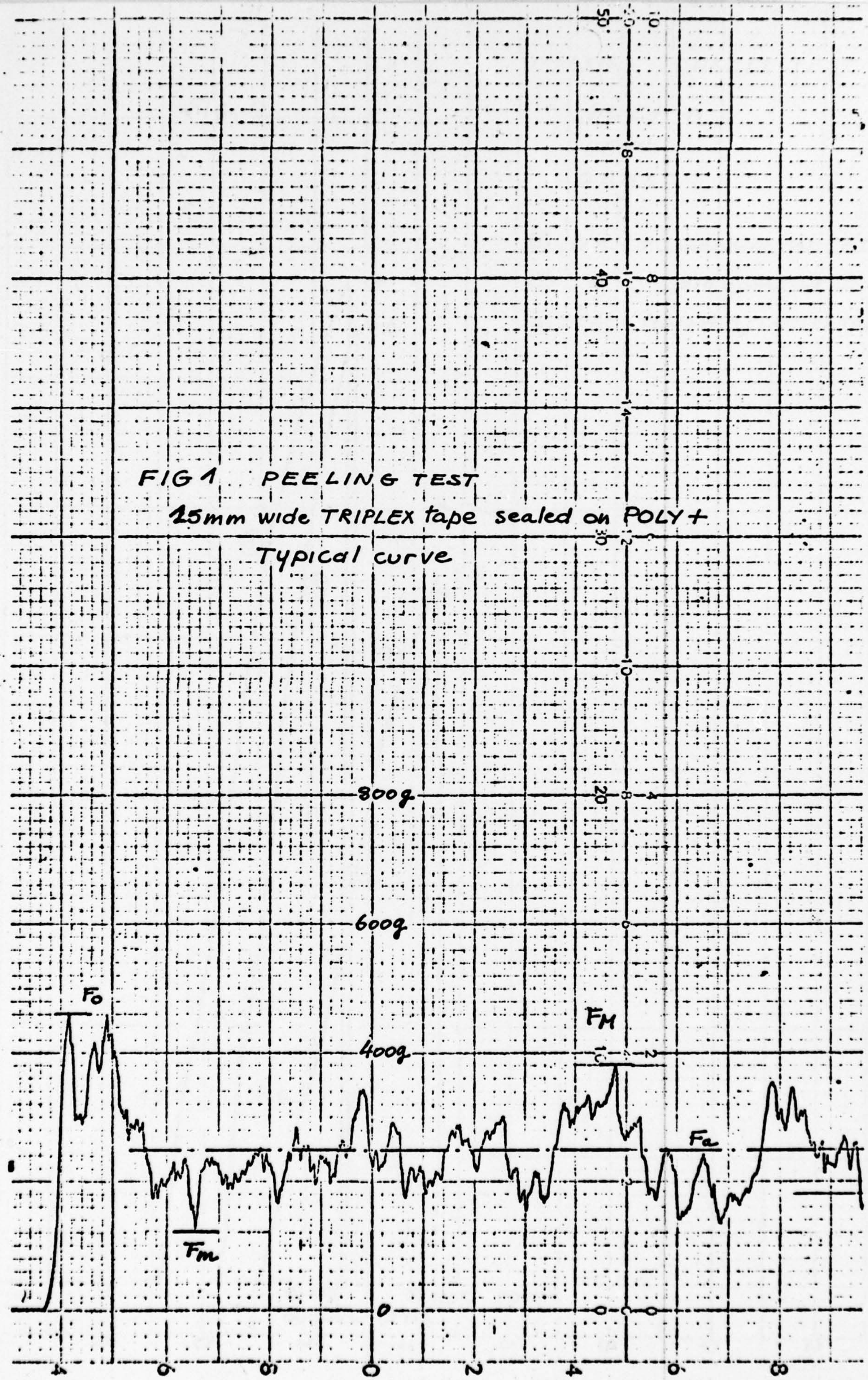


FIG 1 PEELING TEST
15mm wide TRIPLEX tape sealed on POLY+
Typical curve

POLY-PLUS DEVELOPMENT PROGRAM

SUMMARY & STATUS

FEBRUARY 1974

PREPARED BY

G. T. SCHJELDAHL COMPANY
ADVANCED PROGRAMS DIVISION
NORTHFIELD, MINNESOTA

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POLY-PLUS DEVELOPMENT PROGRAM - SUMMARY AND STATUS

Schjeldahl, under the sponsorship of the National Scientific Balloon Facility and the Office of Naval Research, has been examining the feasibility of employing Dacron yarn-reinforced polyethylene film (Poly-Plus) and new fabrication techniques and equipment to produce free flight, heavy load balloons at a significant cost saving compared to the conventional Mylar-scrim heavy load balloons.

This report summarizes the overall scope and schedule of the Poly-Plus Program which has been on-going for the last several years and, more importantly, presents the status of the program - what has been done, results to date, and work remaining to be accomplished. For purposes of brevity, the program summary and status is identified in the attached Figures 1 and 2 and Tables 1 and 2. A more general discussion follows.

Feasibility of producing reinforced polyethylene was examined under an earlier contract with NSBF. The structural properties achieved in this material were equal or superior to those of Mylar-scrim.

During 1973, various seam techniques and sealing equipment were examined. This study uncovered work being done by French balloon manufacturers in sealing of unsupported polyethylene film balloons having taped, butt joints similar to those used in Mylar-scrim balloons. This seam configuration is known to give much higher joint efficiencies than the usual polyethylene fin seal but is prohibitively expensive when made on conventional, low speed American equipment. The exciting aspect of the French sealing method is that production speeds are nearly equal to those of polyethylene, fin seal equipment (i.e. 30 to 40 ft/min).

As a result, the Poly-Plus Program was modified to include production of additional poly-plus which was supplied to the French for evaluation on their sealing equipment in the presence of NSBF, ONR and Schjeldahl representatives.

The results were so encouraging that a joint program was outlined, reflected in this report, involving French and United States balloon users and manufacturers to continue development of the material and technology required for balloon fabrication. In brief, the United States would assume responsibility for balloon design and for production of the poly-yarn laminates. Using these, the French would fabricate a 50,000 cubic foot test balloon which would be instrumented and inflated in an enclosed building in the United States for design evaluation testing. There would be no interchange of funds between France and the United States. At the conclusion of this test, an evaluation report would be prepared by Schjeldahl summarizing the results of all phases of the program and presenting price estimates for manufacturing various size Poly-Plus balloons. These prices would be based upon actual material fabrication price data and real sealing rates experienced by CNES/Zodiac in building the test balloon.

It appears now that, depending upon the availability of funding, that the Poly-Plus Program will be completed during the calendar year 1974. Assuming that the results of the program verify the cost effectiveness of Poly-Plus balloons (i.e. the program is successful), the following list of problem areas must be addressed:

A. Once cost effectiveness is verified, it still remains to build and flight test a representative size Poly-Plus Balloon (i.e. a 3,000,000 ft^3 volume balloon). This is the final proof of price and performance. It is recommended by Schjeldahl that

this work should be accomplished in the Government's FY '75 with a flight test in the summer of 1975. Assuming the Development Program is successful, funding required is estimated as follows:

. Non-Recurring ------------------	\$ 30,000
(Design, Drawings, Component Test)	
. Fabrication --------------------	\$ 12,000
. Flight Test Support-------------	\$ 2,000
TOTAL	\$ 44,000

B. Implementation of (A) above requires the purchase, installation, and checkout of the high speed, gore cutting and sealing equipment that has been developed by CNES. This equipment, which is key to low balloon fabrication costs, can be purchased from CNES and installed in Schjeldahl's plant. Based upon conversations with CNES, the price to purchase this equipment (i.e. Chinese copy) is approximately \$45,000. An additional \$10,000 would be required for its installation and checkout.

It is recommended by Schjeldahl that a Poly-Plus Program coordination meeting be held at Schjeldahl's plant sometime in May of this year to discuss the contents of this document, update schedules, and review responsibilities and funding for the remaining work. Since NSBF is the lead group on Poly-Plus, it is recommended that Mr. Mike Pavey coordinate such a meeting.

TABLE I

POLY-PLUS DEVELOPMENT PROGRAM CONTRACT SUMMARY

	ACTIVITY	SPONSOR	CONTRACT PRICE	EST. PRICE
1.	Program Definition	NCAR/ONR/GTS	N/A	N/A
2.	Hand Samples	NCAR	$5,500	
3.	Initial Machine Run	NCAR	7,500	
4.	Pilot Run Lamination	ONR	1,500	
5.	Fin Seal Test	NCAR	4,700	
6.	Tape Seal Fab/Test	ONR/CNES	1,500	
7.	Tape Seal Test/Selection	ONR	1,800	
8.	Hardware Design	ONR	4,500	
9.	Hardware Test	ONR	1,000	
10.	Appendage Design	TBD		$8,800
11.	Appendage Test	TBD		1,000
12.	Balloon Matl. Lam.	NCAR	6,800	
13.	Balloon Drawings	TBD		9,000
14.	Hardware Fabrication	TBD		1,500
15.	Envelope Fabrication*	CNES/Zodiac		4,000
16.	Balloon Assembly	TBD		5,000
17.	Balloon TEST	NCAR		5,000

*Activity No. 15 to be performed by CNES at no cost in Zodiac plant in Toulouse, France. GTS to witness fabrication.

FIGURE 1

POLY-PLUS DEVELOPMENT PROGRAM

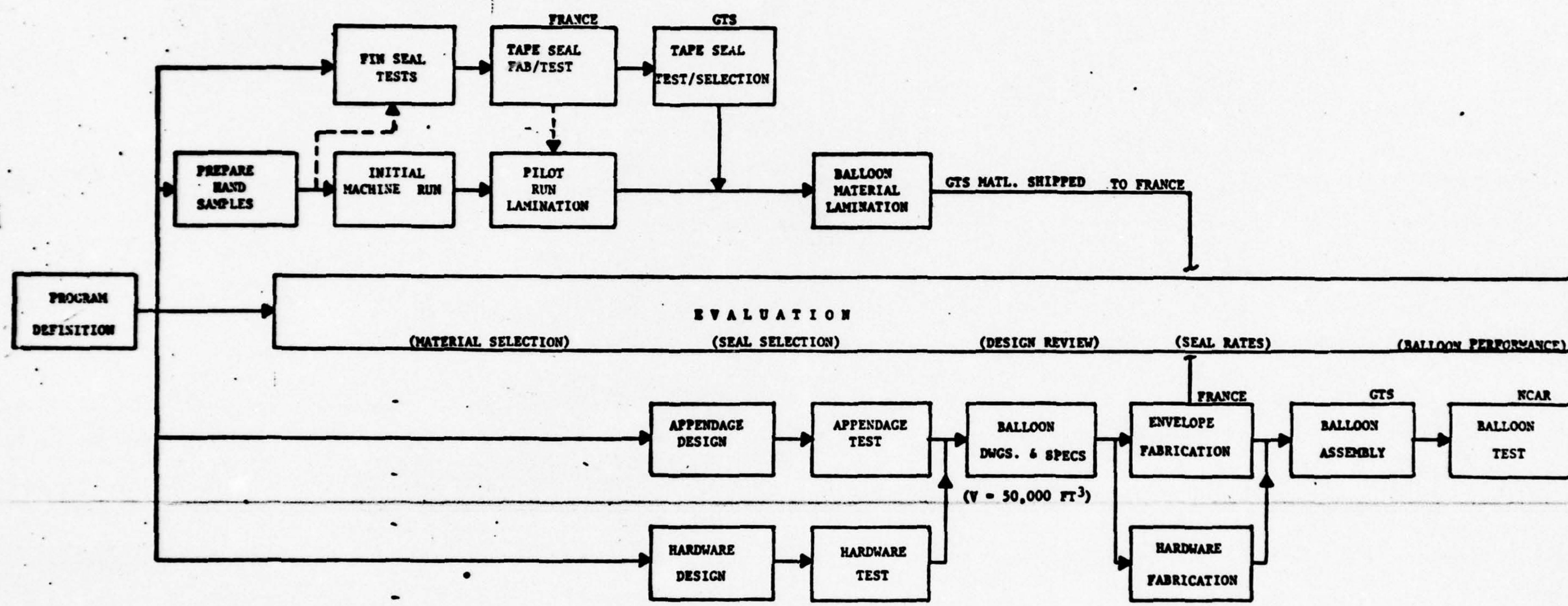

TABLE II

POLY-PLUS DEVELOPMENT PROGRAM

OBJECTIVE/STATUS

OVERALL PROGRAM OBJECTIVE:

Develop heavy load, natural shape balloon constructed from yarn reinforced polyethylene film (Poly-Plus) which is significantly more cost effective than yarn reinforced polyester balloons and which is price/performance competitive with poly balloons. The program will result in the actual fabrication and hangar test of a 50,000 ft^3 volume Poly-Plus Balloon plus an evaluation report projecting price and performance of several typical size balloons.

DETAIL OBJECTIVES & STATUS

ACTIVITY	OBJECTIVE	STATUS
1. Program Definition	Program objectives, schedules and scope of work.	Complete.
2. Hand Samples	Define adhesive system and application technique to bond yarn and poly film.	Adhesive system having acceptable bond and blocking characteristics was defined.
3. Initial Machine Runs	Define process parameters for manufacture of laminate.	Tentative values of web tension, lamination temperature, pressure and speed were identified.

ACTIVITY	OBJECTIVE	STATUS
4. Pilot Run Lamination	Produce sufficient yarn-film laminate for sample butt seam fabrication and tests on French sealing equipment.	Laminated $\sim$700 feet of material and shipped it to France.
5. Fin Seam Tests	Define fin-type seam configuration suitable for fabrication on existing or modified poly balloon sealing equipment.	Identified several fin seams having satisfactory bond. When tensile stressed, film tore at points where yarn entered bonded area on all samples tested. Fin seams abandoned in favor of taped, butt seams made on French-designed sealing equipment.
6. Seal Fab and Test Tape	Define taped butt seam configuration which can be made on the French sealers.	Several configurations produced and tested by CNES/Zodiac in presence of NCAR, ONR and GTS representatives. Samples sent to GTS for further testing.
7. Tape Seal Test and Selection	Repeat tests at GTS on several type tape seams to verify tests conducted by French. Perform biaxial tensile test with shear on seam specimens.	Biaxial seam test with shear showed superiority of butt seams over fin seams. Seal type selection not yet made.
8. Hardware Design	Define suitable end fitting termination for use with yarn reinforced polyethylene.	Contract issued by ONR - no effort yet expended.
9. Hardware Tests	Apply simulated service load to end fitting - laminate interface to verify design suitability.	Contract issued by ONR -no effort yet expended.
10. Appendage Design	Define seams attachments and envelope opening reinforcement for duct and inflation tube appendices.	Not funded.

	ACTIVITY	OBJECTIVE	STATUS
11.	Appendage Tests	Apply simulated service load to attachment design to verify suitability.	Not funded.
12.	Lamination of Envelope Material	Manufacture sufficient laminate to build test balloon and conduct appendage tests.	Film and yarn on hand. Lamination run delayed about 2 months due to movement of FTL machine to new location.
13.	Preparation of Drawings & Specs	Document design of test balloon.	Specification for material is complete. Design drawing effort not yet funded.
14.	Fabricate Hardware	Manufacture end fittings for test balloon.	Not funded.
15.	Balloon Fabrication	Fabricate a 50,000 ft^3 test balloon in accord with drawings.	Written agreement with French principals obtained regarding cost and scope of work.
16.	Balloon Assembly	GTS to receive balloon envelope from France and install end fittings and other hardware.	Not funded.
17.	Balloon Test	Inflate test balloon, measure lift loss, and stress, and visually inspect envelope.	Not funded.

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POLY-PLUS SEAM STUDY:
CYLINDER TESTING

J.B. Munson
Sheldahl Company
Advanced Products Division
Northfield, Minnesota

May 1974

Interim Report Covering Period from July 1973 to May 1974

Prepared under Contract No. N00014-72-C-0494

for
Office of Naval Research
Department of the Navy
Arlington, Virginia

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List of Figures

1.0 INTRODUCTION

Sheldahl, under sponsorship of the Office of Naval Research and the National Scientific Balloon Facility, has been studying the use of Poly Plus material for free flight, heavy load balloons as a significant cost savings compared to conventional Dacron* reinforced, Mylar* balloons. Poly Plus is a generic name for polyethylene film reinforced with multiaxial arrays of equally spaced, parallel yarns, adhesive bonded to one side of the film and intended for use in balloons and similar flexible structures (see Figure 1). The film thickness, and the spacing, angle and size of the yarns may be varied to suit different applications.

The feasibility of manufacturing Poly Plus was verified under an earlier contract with NSBF (Reference 1). The structural properties achieved were equal to or superior to those of Dacron reinforced Mylar counterparts.

During 1972 and 1973, various seam technologies were examined. Taped, butt-type seams, similar to those used on reinforced Mylar balloons were shown to yield higher joint efficiencies than the fin, heat seal commonly used on unreinforced, polyethylene balloons. However, butt-type seams are normally several times more expensive than fin seams because of low process speeds afforded by most conventional equipment. Equipment recently developed in France forms butt-type seams at speeds comparable to current fin seaming equipment (30 to 50 feet per minute). The development program was modified to include evaluation of this equipment for seaming Poly Plus.

Butt-seam specimens on Poly Plus using a wide variety of tapes were manufactured and tested in France by Zodiac Espace, Toulouse by arrangement

*DuPont Trademark.

with the Balloon Systems and Projects Division of the Centre National D'Etudes Spatiales (CNES). Satisfactory seams were readily achieved and the test results on the various configurations were so similar that selection of the best combination was difficult.

The field of alternatives was reduced to three. Specimens of these on Poly Plus were incorporated into cylindrical sleeve specimens and tested by Sheldahl under biaxial tensile and shear loading to further characterize the material and seams.

A considerable number of very small holes was found in the film during the cylinder tests. An investigation was conducted to determine the cause and corrective action.

2.0 TEST SPECIMENS

2.1 Base Material

The particular Poly Plus configuration used for the seal evaluations described herein consisted of 1.0 mil thick Stratofilm* reinforced with 220 denier, high tenacity, Dacron yarns as illustrated in Figure 1. The material was manufactured by Sheldahl on custom laminating machinery equipped for positioning the yarns.

2.2 Cylinder Test Specimens

Sleeves incorporating the three seam types were manufactured by Zodiac in France. All seams incorporated "edging", "overlapping" and "bi"-tapes as shown in Figure 2. All tapes used were approximately 25 mm (1 inch) wide. The tapes designated in Figure 2 have the following make-up:

- 12.12R.12 - 0.5 mil Terphane** film (oriented in the machine direction) coated with 0.5 mil of polyethylene on both sides
- 12.12G.18 - 0.5 mil Terphane film reinforced with 220 denier yarns (2/inch in M.D. and 5/inch in T.D. at 84^{o} to M.D.). The film side is coated with 0.5 mil of polyethylene and the yarn side with 0.75 mils of polyethylene.
- GT-300 - 1.0 mil Mylar film coated on one side with 1.0 mil of thermoplastic, polyester adhesive.
- GT-12 - 0.5 mil Mylar film reinforced with a leno weave, Dacron scrim (220 denier in an 8/in. x 12/in. weave). The yarn side is coated with 1.0 mil of thermoplastic, polyester adhesive.

*T.M. Winzen, Research Inc.
**A polyester film manufactured in Europe.

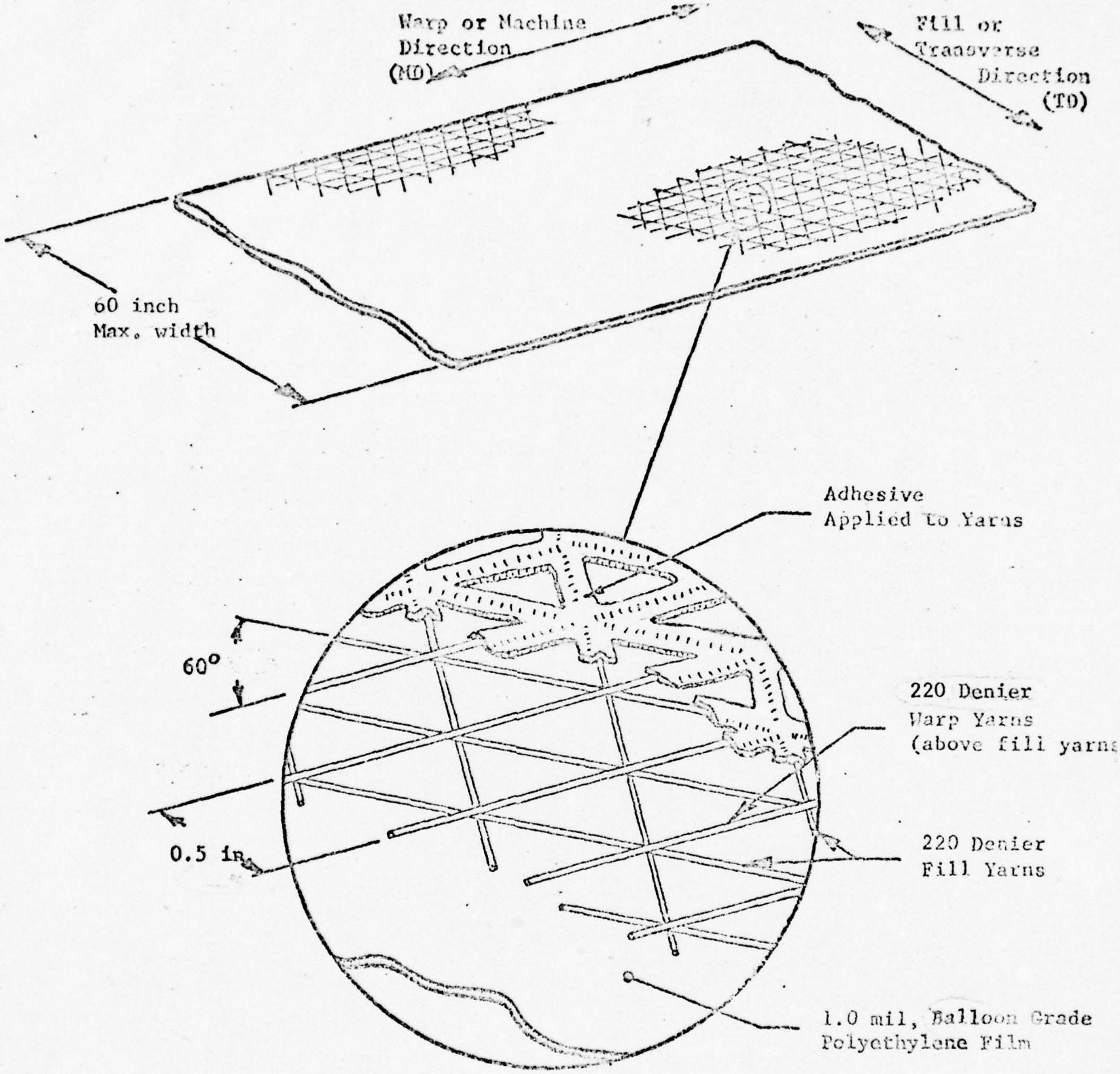
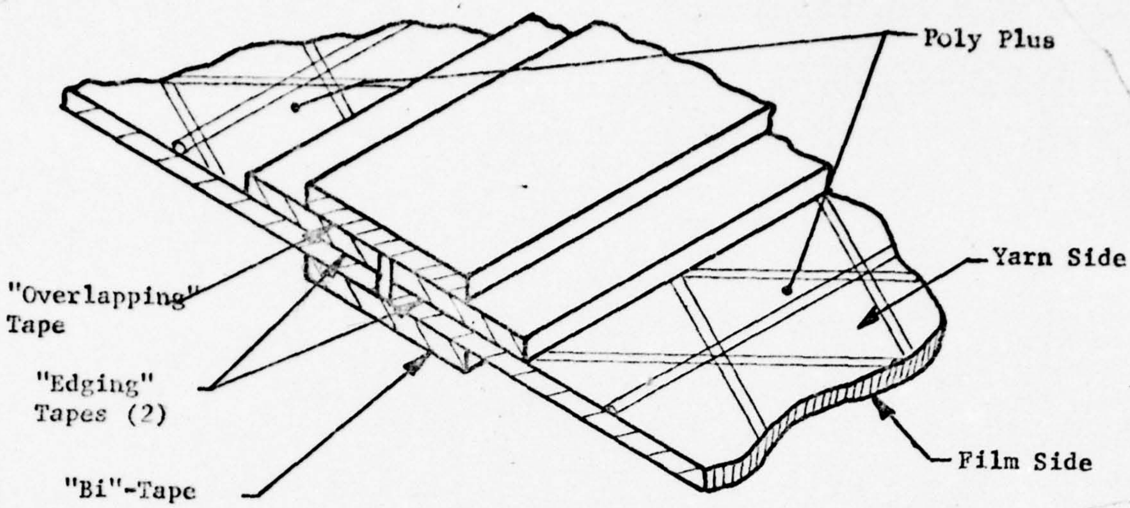


Figure 1. Configuration of Poly-Plus Composite Used in Seal Evaluations



Tape Nomenclature

Seam Type	Edging Tape	Overlapping Tape	Bi-Tape	Location of Edging Tape
1	12.12R.12	12.12R.12	GT-300	Film side of Poly Plus
3	12.12R.12	12.12G.18	GT-300	Film side of Poly Plus
4	GT-300	GT-12	12.12R.12	Yarn side of Poly Plus

Figure 2. Configuration of Seams Used on Poly-Plus Cylinder Test Specimens

A noteworthy feature of these seams is the edging tapes which are applied at the time the panels (of Poly Plus) are cut to profile. Edging tapes are bonded to the panel edge with a heated wheel in which a thermal gradient is maintained along its axis from a high temperature at the wheel face near the panel edge to a lower temperature at the wheel face nearest to the panel center. This graduates the strength of the bond transverse to the seam and

reduces the large stress discontinuously ordinarily produced at the edges of uniformly bonded, lap-joints. The overlapping tape and the bi-tape are thermally bonded in place when the edged panels are butted together.

The cylindrical sleeves, 44 inches in circumference, consisted of three rectangular panels of Poly-Plus joined by three identical seams parallel to the sleeve axis. Sufficient sleeving was furnished to make at least five sleeve test specimens each 50 inches long.

Prior to cutting the sleeve panels, Zodiac inspected the Poly-Plus and marked anomalies in the yarn pattern such as broken or displaced yarns. Several small (0.02 inch to 0.05 inch diameter) holes in the film were also identified. A number of additional holes were located by Sheldahl when the cylinder specimens were mounted on the test fixture (Para. 3). An investigation was made to determine the cause of the holes.

2.3 Coupon Specimens of Seams

Uniaxial tensile tests on seams cut from surplus sleeve material were conducted to compare the efficiency of the various seam types.

3.0 TESTING

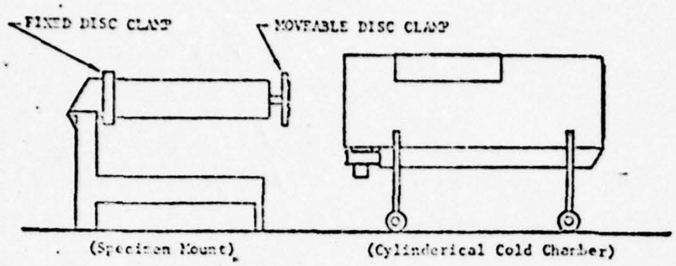
3.1 Cylinder Test Apparatus

The general arrangement of the test fixture is shown in Figure 3. The fixture consists of a fixed circular end plate and a moveable end plate of the same size. When a cylindrical sleeve of flexible material is clamped to the plates, Figure 3(d), tensile stresses may be applied to the sleeve by internal pressure and by axial displacement of the moveable end plate. The moveable end plate is rotated about the common axis to apply shear loads to the sleeve.

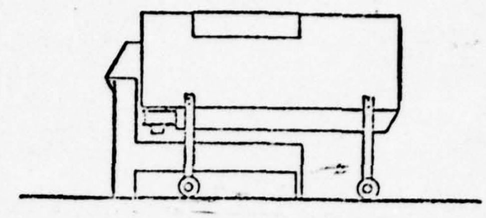
Specimen grips consist of rubber gaskets placed inside and outside the sleeve and a band clamp positioned around the periphery of the two end plates (Figure 3d).

An environmental chamber, Figure 3(e), fits over the mounted sleeve specimen. Liquid nitrogen, vaporized in the lower duct is circulated over the specimen. The temperature is controlled by a conventional, set-point control module with feedback provided by thermocouples mounted inside and outside the specimen.

A more detailed discussion of the apparatus is contained in Reference 3.

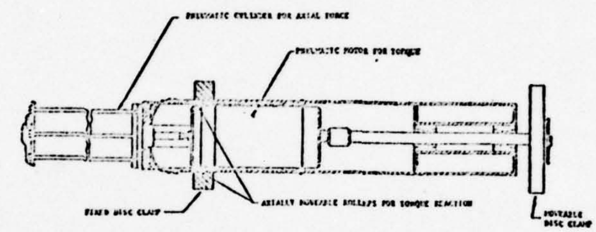


(a) Chamber and Specimen Mount Separated

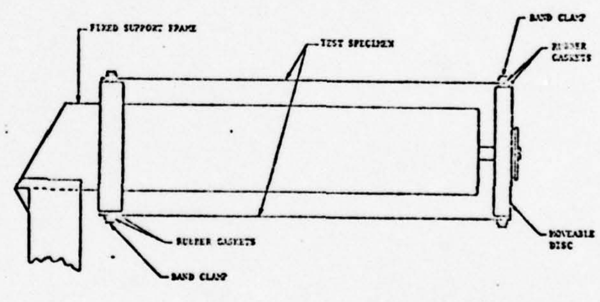


(b) Chamber Positioned over Specimen Mount

(c) Cross Section of Specimen Mount Showing Drive Elements



(d) Cross Section of Mounted Specimen



(e) Cross Section Showing Air Circulation in Cold Chamber

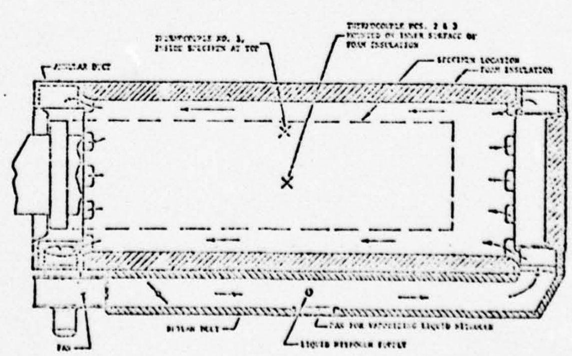


Figure 3. Construction Details of Cylinder Test Apparatus

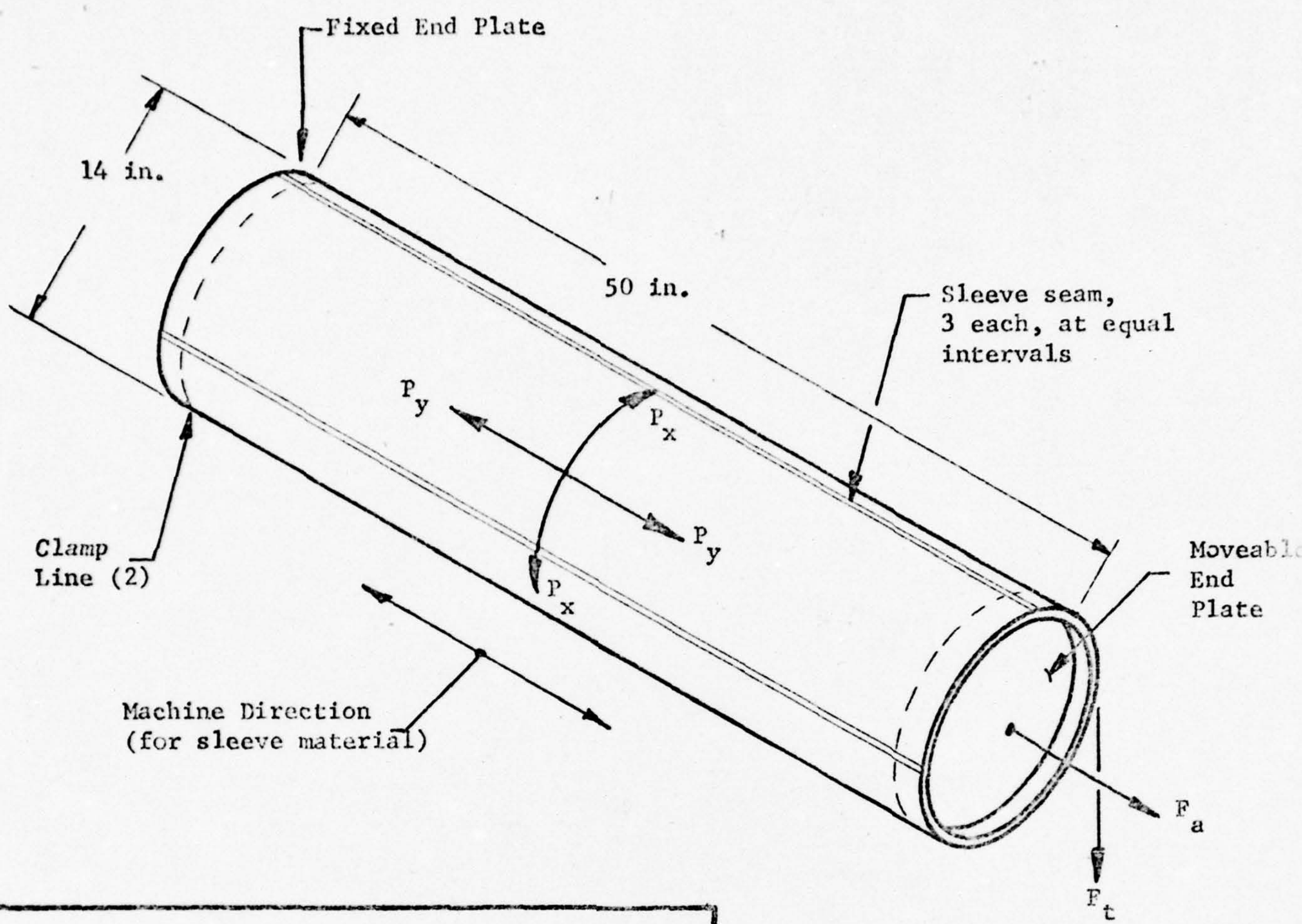
3.2 Cylinder Test Procedure

The cylindrical specimens were mounted by sliding them into position over the moveable end plate. After applying the rubber gaskets and making certain that the sleeve was free from twists and wrinkles, the band clamp was securely tightened over each end plate.

A small (5 to 10 inches H_2O) internal pressure was applied to the sleeve and the surface inspected for small leaks. Small holes were located in all of the cylinders tested. The leaks were covered with patches of 3M Y491 tape to permit better control of internal pressure during the test.

After positioning the cold chamber over the specimen, the coolant flow was started and the specimen temperature lowered to $-90^{\circ} \pm 5^{\circ}F$ ($-68^{\circ} \pm 2^{\circ}C$). Internal air pressure and the load on the axial drive were raised to predetermined levels and the moveable end plate was rotated until failure occurred. Relations between material load and test fixture drive forces are indicated in Figure 4.

The hoop (transverse direction) and axial (machine direction)loads were selected to simulate the load conditions which might reasonably exist in the wall of a free flight balloon during ascent and deployment. Although little empirical or analytical data are available characterizing such load distributions, examination of balloon envelopes which failed during deployment indicates that high shearing forces may be applied, particularly where loads are transferred between bubbles or "ears" of gas near the balloon top to the undeployed reserve of material near the balloon axis. For the tests described, a constant transverse force of about 1.3 pounds per inch was maintained to minimize buckling of the specimens. The axial (machine direction) load corresponding to the meridional load in a balloon was set at different values in



Transverse Direction Force	$P_x = PR$
Machine Direction Force	$P_y = PR/2 + F_a/(2\pi R)$
Shear Force:	$P_{xy} = F_T/(2\pi R)$

P_x, P_y, P_{xy} = Respectively, the hoop, axial and shear membrane force in sleeve (lb/in.)

P = Differential air pressure across sleeve wall (lb/in.^{2})

R = Sleeve radius (in.)

F_a, F_T = Respectively, the axial force and tangential force acting on the rim of the moveable end plate

Figure 4. Relations Between Unit Membrane Forces in Cylinder Specimen and Test Fixture Driving Forces

each replicate specimen ranging from 3 to 12 pounds per inch. A shear load was then applied until failure occurred.

Most of the cylinders failed catastrophically. For the rest, failure was assumed to have occurred when internal pressure could no longer be maintained because of localized failure. The cold chamber was then removed and the specimen examined to determine the location and mode of failure.

The principal advantages inherent in the cylinder test method for evaluation of balloon materials like Poly-Plus are:

- Biaxial tensile and shearing loads can be easily applied simultaneously in simulation of the most extreme conditions encountered by free flight balloon materials during deployment.
- The specimen size is very large compared to the yarn spacing and seam width which is more representative of the situation in a balloon structure than the conditions applied for unixial tensile tests of 1 or 2 inch wide strips.
- The biaxial stress field remains uniform over most of the specimen even when the material deforms in contrast to biaxial testing of a circular or elliptical, pressurized diaphragm where the highest stress is always applied at the center.
- Edge effects such as tearing from nicks and scratches in a cut sample are eliminated since the cylinders have no unrestrained edges.

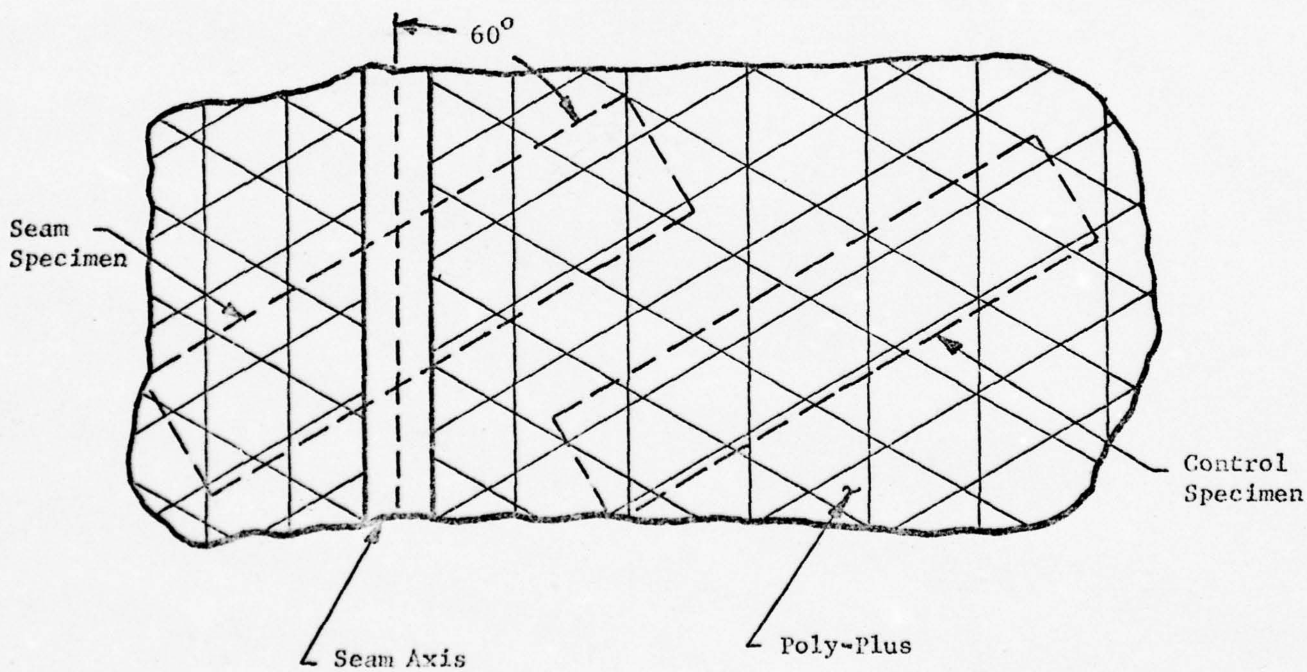
Some of the less desirable features of cylinder testing are:

- Test planning requires much care because of the many possible load combinations and many tests may be required to adequately characterize a material.

- Specimen preparation, specimen mounting and load application generally require considerable time.
- The fabricated diameter of the specimen must be closely controlled to prevent stretching or wrinkling at the clamp line during mounting.

3.3 Uniaxial Seam Tensile Tests

One inch wide specimens were cut parallel to the diagonal, transverse direction yarns and tested at 23°C on an Instron Model 114, in accord with ASTM Method D 882, except the grip separation was increased to 5 inches.



3.4 Film Hole Investigation

The blocking or "sticking" characteristics of the exposed adhesive were evaluated by pressing the adhesive side of 2-inch wide strips of Poly-Plus against various surfaces with a dead load of 5 pounds per square inch. The load was applied for a 24-hour period at 23°C and 65°C (150°F) and the force required to peel off the 2-inch strip was measured on an Instron testing machine. At least three specimens were tested at each of the following conditions, using Poly-Plus material from a cylinder specimen that had a particularly large number of holes.

Condition	Temperature at 5 psi, 24 hours	Surface in Contact with Adhesive Side of Poly-Plus	Surface Treatment
1	23°C	Adhesive side, Poly-Plus	None
2	65°C	Adhesive side, Poly-Plus	None
3	65°C	Adhesive side, Poly-Plus	Dusted with powdered talc
4	65°C	Adhesive side, Poly-Plus	Dusted with cornstarch
5	65°C	Film Side, Poly-Plus	None

This test is a standard method used to determine the blocking characteristics of coatings and exposed adhesives on balloon materials. The temperature and pressure are representative of extreme conditions to which the folded balloon material may be subjected during storage. Condition 1 corresponds to temperatures likely to be encountered during balloon assembly. Condition 5 corresponds to the arrangement produced when a strip of material is wound on itself in roll form for storage purposes.

4.0 RESULTS

4.1 Cylinder Tests

Cylinder test failure data for the three seam types are presented in the table below, and plotted in Figure 5.

Cylinder Test Failure Data at -90°F for Three Types of Poly-Plus Seams

Seam Type	Sample Letter	Membrane Force at Failure (lb/in.)		
		Hoop (P_x)	Axial (P_y)	Shear (P_{xy})
1	A	1.26	3.6	5.04
	B	1.26	6.6	6.27
	C	1.26	9.6	4.66
	D	1.26	12.61	2.47
	E	4.04	7.96	2.42
3	A	1.26	12.61	4.06
	B	1.26	12.6	3.67
	C	1.23	9.6	3.23
	D	1.18	6.57	4.07
	E	1.21	3.58	4.01
4	A	1.26	3.61	4.75
	B	1.26	6.61	3.81
	C	1.26	9.61	2.97
	D	1.26	12.61	0.0
	E	1.26	12.61	0.0

The trend of the data for seam types 3 and 4 is similar to the cylinder test data reported in Reference 1. Cylinder seams for the tests in Reference 1 were similar to seam type 4, except no edging tapes were used and the bi-tape was GT-300 tape.

Figure 5 indicates that seam type 1, which has no yarn reinforcement in the overlapping tape, will sustain slightly higher shear loads for axial loads from about 5 to 10 pounds per inch.

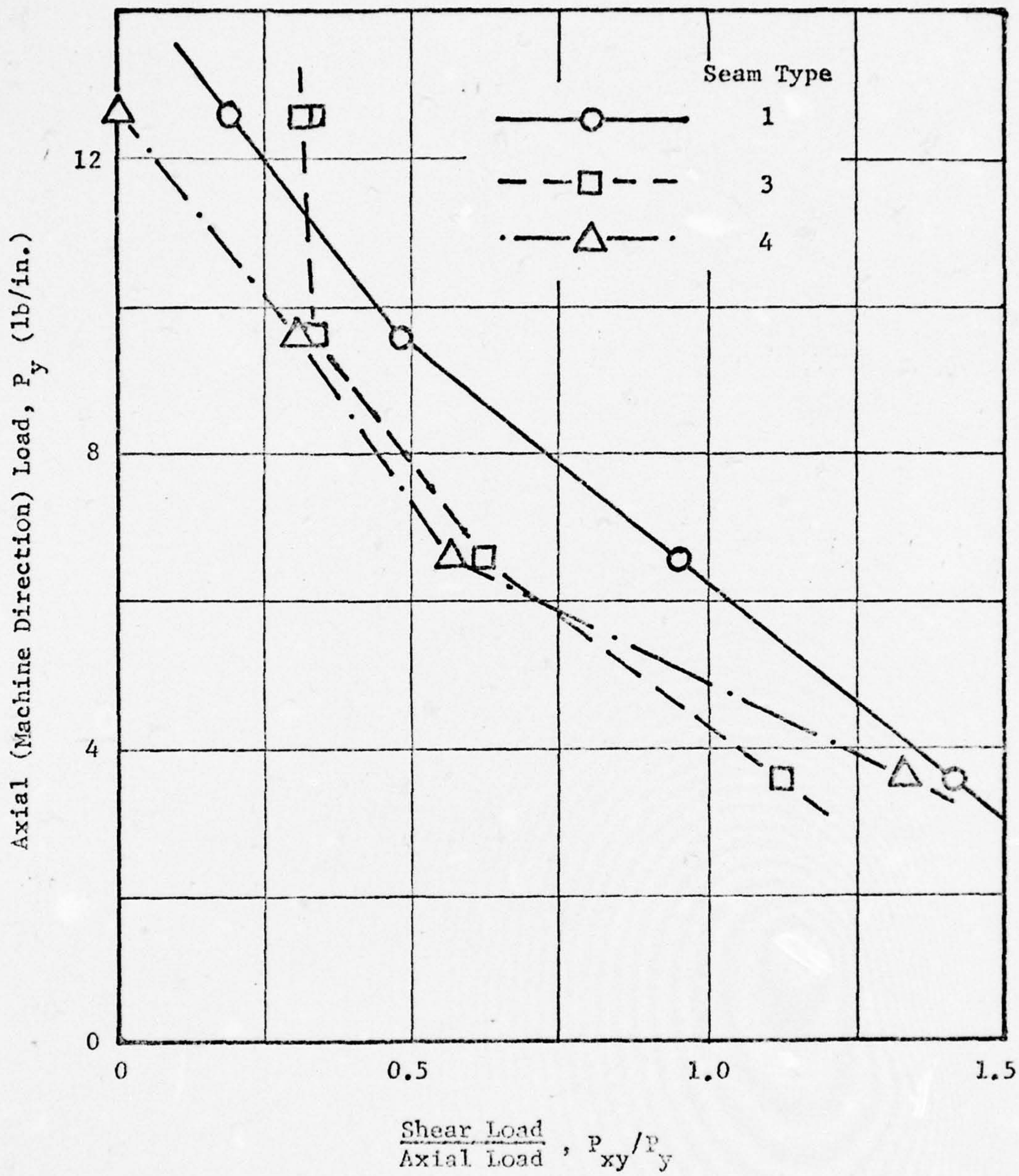


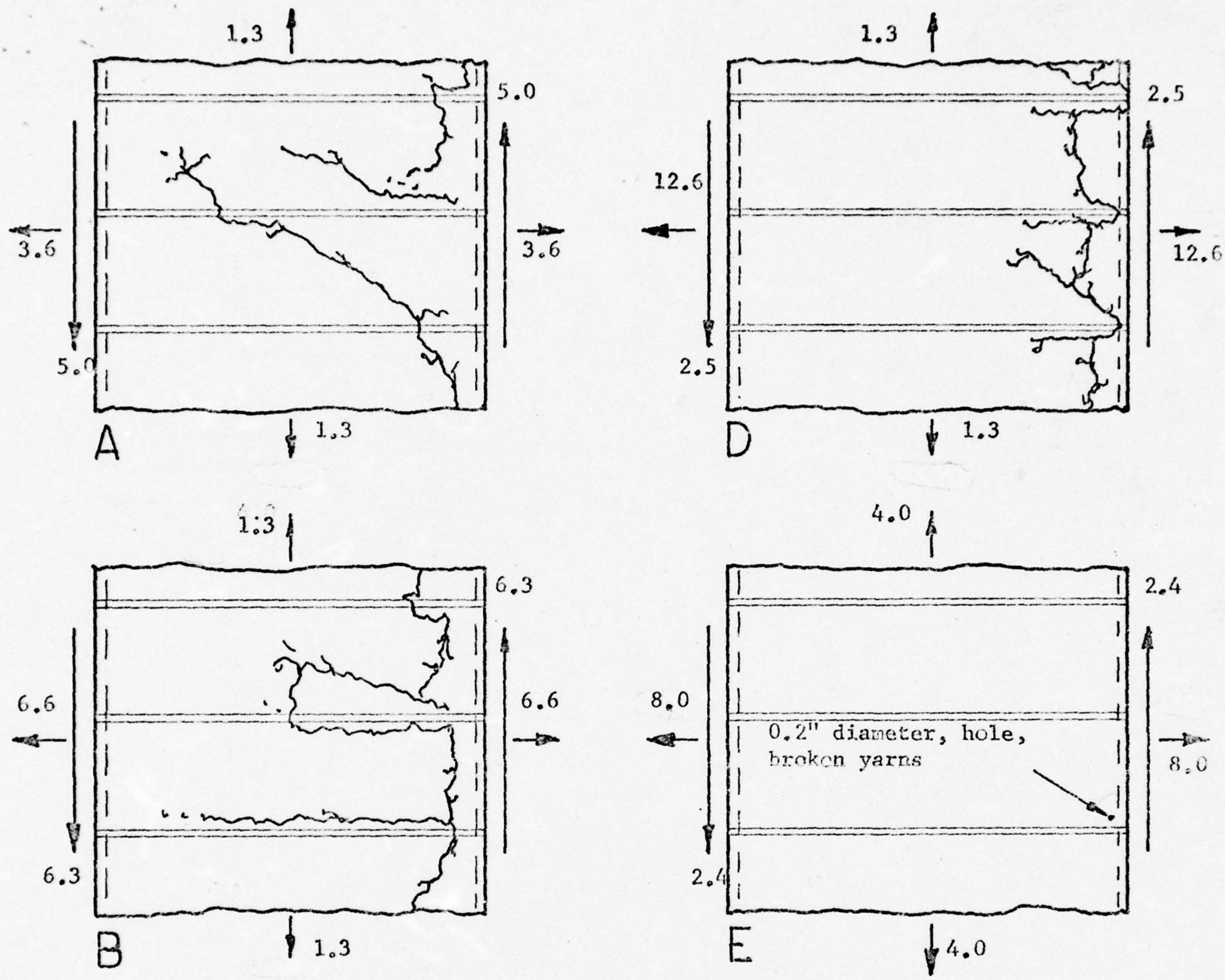
Figure 5. Poly-Plus Cylinder Failure Data for Three Types of Seams at $-90^{\circ}F$ and a Hoop Load, P_x = 1.3 lb/in.

Figures 6, 7, and 8 illustrate the pattern of failure exhibited by each cylinder specimen tested. The diagrams represent the cylinder surface when the sleeve is cut parallel to the axis and layed flat. The cylinder end at the right in each diagram was clamped to the moveable end plate. Most of the failures occurred nearest to the moveable plate which may be attributed to the temperature difference along the specimen axis. Coolant circulated over the specimens from right to left, producing a temperature gradient of about $1^{o}F/ft$.

The material tended to fail along the transverse direction (TD) when the machine direction (MD) load was high (Figure 6D, Figure 7A and B and Figure 8D and E). Similarly, when shear loads were high compared to MD and TD loads, failure occurred diagonally at an angle approximately 90 degrees from the direction of principal stress (Figure 6A, Figure 7C, D, and E, and Figure 8C). A considerable number of localized failures occurred in the angle formed by a seam and the clamped end (Figure 6C and E, Figure 7C and Figure 8A and B).

The undesirable effect of overlapping tapes which have yarn reinforcement in the machine direction, like seam type 4, is shown by the failure pattern in Figure 8D and E. The higher modulus along the seam axis due to the extra overlapping tape yarns caused cylinder failure to originate in the seam when the axial load was raised to 12.6 pounds per inch before any shear load was applied.

Virtually all of the failures, whether localized or general, were accompanied by yarn fractures along the path of the tear in the film. This is in contrast to the cylinder failure patterns noted for Mylar, polyester film reinforced with Dacron (Reference 3) which typically involves film rupture only, leaving the yarns intact. This may be attributed to the greater yarn modulus to film modulus ratio for Poly-Plus compared to reinforced Mylar.



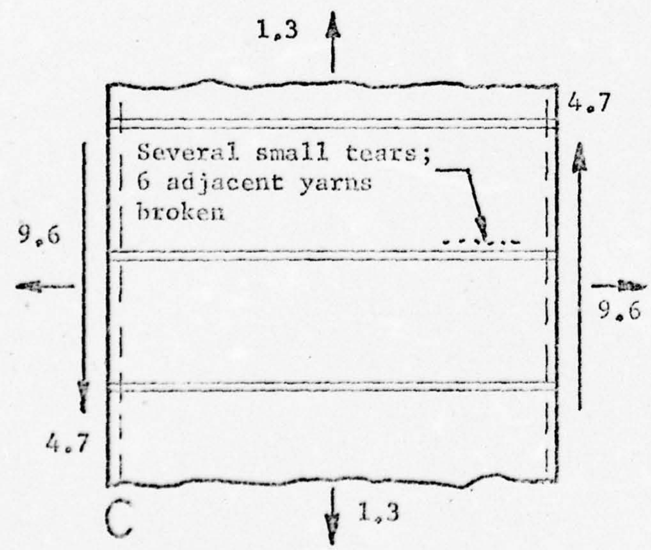


Figure 6. Cylinder Specimen Failure Pattern and Membrane Force at -90°F for Seam Type 1. (Force data in lb/in.)

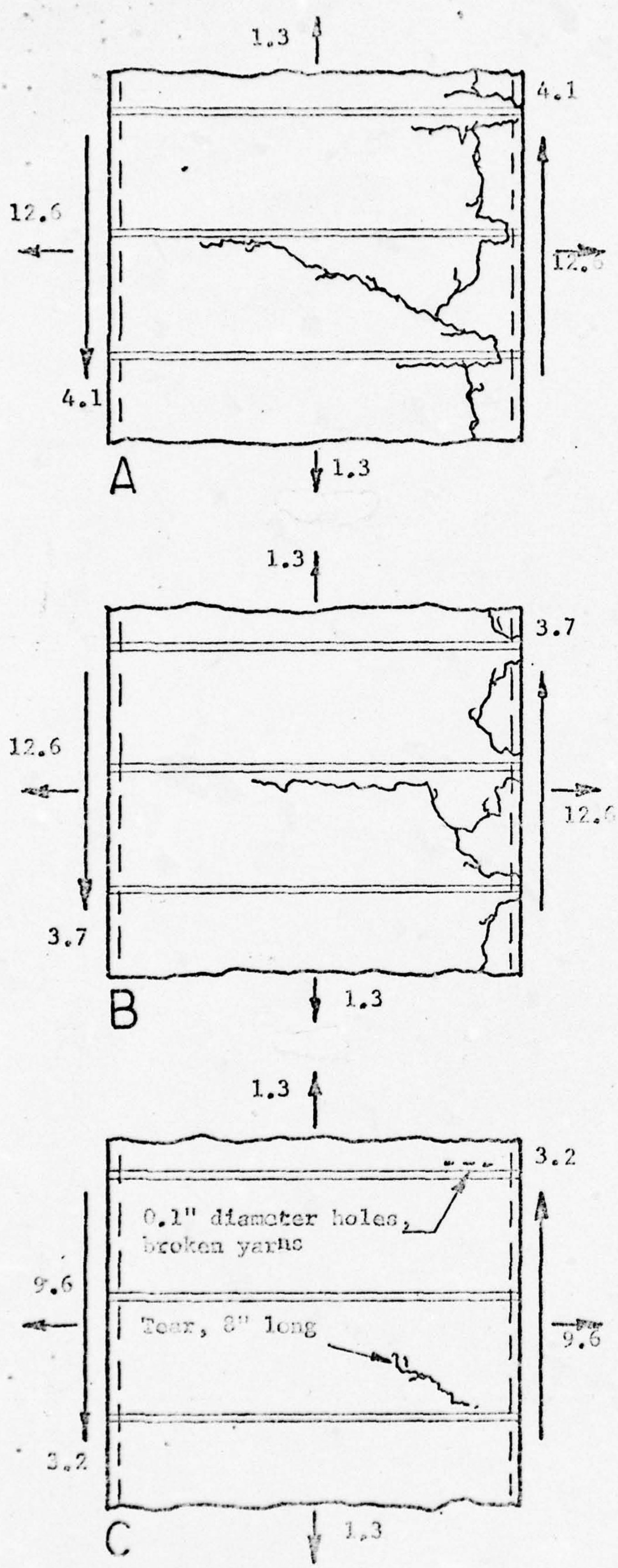


Figure 7. Cylinder Specimen Failure Pattern and Membrane Forces at -90°F for Seam Type 3 (Force data in lb/in.)

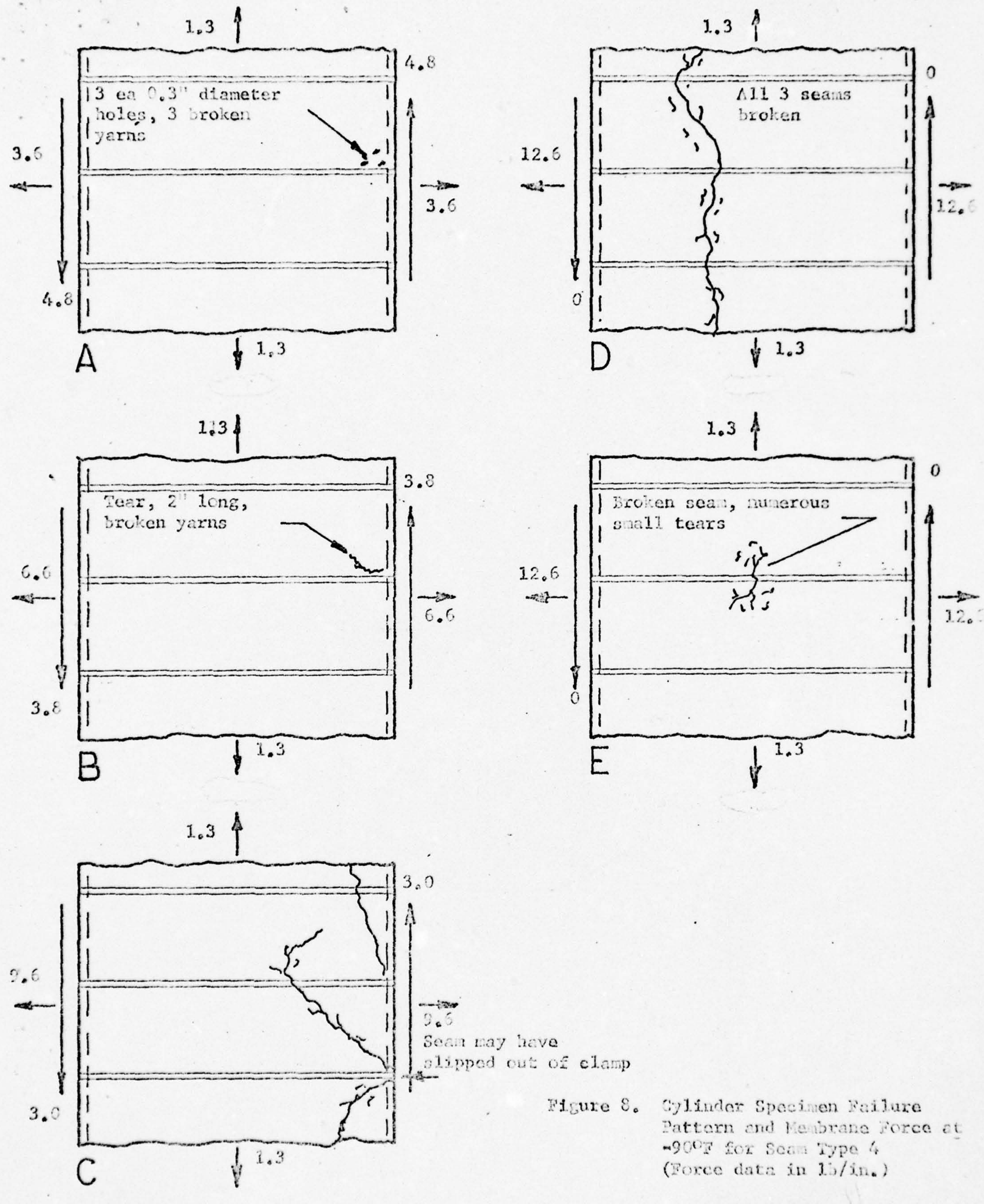


Figure 8. Cylinder Specimen Failure Pattern and Membrane Force at -90°F for Seam Type 4 (Force data in lb/in.)

Based on small deflection-linear strain theory, Reference 4 shows that yarn stress at failure for a Dacron-polyethylene composite like Poly-Plus will be considerably higher than for one of Dacron and polyester film.

4.2 Uniaxial, Seam Tensile Tests

The break strength at 23°C in pounds per inch of five, one-inch wide coupons cut on the diagonal (para. 3.3) are given below:

Material	1	2	3	4	5	Average
Seam Type 1	9.3	9.0	9.4	9.3	9.4	9.3
Seam Type 3	9.6	9.3	9.2	9.7	9.3	9.4
Seam Type 4	9.8	9.2	9.3	9.3	9.3	9.4
Control	9.3	9.3	9.2	9.3	9.9	9.4

These results do not represent the true strength at 60 degrees to the machine direction since half of the transverse yarns were severed in cutting the one-inch wide samples. They do indicate that all of the seam types have nearly equal capacity to transfer the load from one panel of Poly-Plus to the other.

4.3 Film Hole Investigation

Examination of the holes discovered in the film under magnification of 50 to 1 and 100 to 1 clearly showed that a small piece of film was missing in each and that the edges of the holes were stretched and rippled, characteristic of room-temperature tearing of polyethylene film. It was also noted that the holes appeared at various locations along straight marks on the film of the same width as the yarn. These marks were probably caused by yarns laid against the film when the material was folded for shipment. The missing area of film in each hole is characteristic of "point blocking" or localized adhesion

of the film to the next layer of material when the material is wound in rolls or folded. Punctured holes as caused by penetration of the film by a hard sharp particle or corner would normally have all of the original material attached around the opening.

The results of the blocking tests described in 3.4 were as follows:

Condition	1	2	3	4	5
Blocking Force (g)	< 0.01	50 ave., 500 max.	< 0.01	< 0.01	< 0.01

The Instron measurement threshold is 10 mg. At condition 5, the surface remainded bonded until a force less than this threshold was applied. At conditions 1, 3, and 4, the weight of the 2-inch specimen was sufficient to separate the surface when the specimens were picked up. For condition 2, about half of the specimens exhibited at least one small (0.05" diameter) section of film torn out of the film by point blocking to an adhesive coated yarn on the neighboring surface. Under magnification, these holes resembled holes found in the cylinder specimens.

5.0 CONCLUDING REMARKS

As observed in a previous evaluation, Reference 2, the strength of the various seams tested is very similar when applied to the particular Poly-Plus configuration. Seams of type 1 with unreinforced tapes, appear to carry equal or higher loads than the other two types. Seam type 3 permitted the Poly-Plus to carry slightly higher combined loads as indicated by the consistent general failures, Figure 7. Type 4 seams tend to assume a disproportionate share of the load parallel to the seam axis because of extra yarns added with the overlapping tapes. This could cause balloon wall failure at some meridional load below the ultimate strength of the Poly-Plus.

Seam type 1 is probably adequate for fabrication of a balloon from Poly-Plus composites having the same number, angle and size (2 per inch, 60 degrees, 220 denier) for the transverse yarns as the material tested. If more or heavier transverse yarns are used, it may be necessary to use a seam of type 3 with yarns added transverse to the overlapping tape. In these tests, the overlapping tape yarn was set at 84 degrees to the tape axis while the Poly-Plus yarns were set at 60 degrees. Experience with similar tapes on reinforced Mylar balloons indicates that such tape reinforcement is most efficient when the yarn angle matches the angle of the transverse yarns in the material being joined.

The numerous small holes observed in the film of the Poly-Plus cylinder specimens appear to be caused by localized adhesions, or blocking, produced when the material is folded and stored at slightly elevated temperatures (less than 65°C). This condition is obviously unacceptable for a balloon material because of potential leakage problems. Similar difficulties were encountered with Dacron reinforced Mylar in 1960 when this material was initially developed for balloon use. The solution to that problem was to modify the chemical process

and reactants used in curing the adhesive and to apply a powdered release agent such as cornstarch to the adhesive side of the composite.

The results of the blocking tests indicate that:

(a) Holes like those observed in the cylinders are produced when the untreated, adhesive side of the Poly-Plus is folded against a like surface and subjected to a pressure of 5 psi at 65°C for 24 hours. This produces a general, low level bond between the surfaces as well as locallized bonds sufficient to pull out pieces of film.

(b) No significant bonding is observed under the same conditions when the one surface is dusted with powdered talc or corn-starch. Experience with heat seams on polyethylene balloons and adhesive seams on Mylar-Dacron balloons suggests that such powdered agents should not be applied to a balloon until seams are complete to avoid degrading the bonds. Reinforced Mylar balloons are normally treated in this manner by applying cornstarch at the rate of 5 pounds per 1000 square feet. This increases the material weight by 3 to 6 percent.

(c) Peel bond strengths of less than 5 mg per inch are produced at the same conditions when the "adhesive-yarn" side of one piece of material is against the "film" side of another. This reduced effect may be attributed to the film surface treatment (etching by electrical discharge). This treatment is applied only to the side which is bonded to the yarns.

(d) No significant bonds were observed under the same conditions as (a) when the temperature was maintained at 23°C. This

suggests that the material could be handled and folded during balloon assembly without the use of a powdered release agent, provided the temperature in the assembly area is controlled. Since temperature during transport and storage of the completed balloon is difficult to control, a Poly-Plus balloon made with the same adhesive should be dusted with a release powder immediately after assembly.

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11.5 FT. DIAMETER KEVLAR SCRIM BALLOONS

Sheldahl Engineering Report No. 0191

Prepared By:

Loren L. Rueter

Contract N00014-72-C-0494

INTRODUCTION

Sheldahl, under ONR Contract N00014-72-C-0494 (item 11), designed and fabricated two 11.5 ft. diameter (Twerle class) Kevlar scrim (G1345 material) balloons. The instrumented balloons are to be flown by NCAR to obtain supertemperature data for the G1345 material. This is of primary interest since the material is a candidate material for HASPA (High Altitude Superpressure Aerostat). Two candidate solar arrays for HASPA will also be tested under actual flight conditions. The solar arrays are supplied by NRL.

This report covers G1345 material tests, deviations in construction from Twerle specs, and inflation tests.

1.0 MATERIAL

G1345 is a laminate of 1 mil Mylar by 1.0 oz/yd^2 Kevlar 29 scrim (F011600). The Kevlar scrim is 10 x 10 count, 200 denier thread, with a leno weave.

1.1 *SIZING*

Previous runs of this material produced a laminate unsuitable for superpressure balloons. Wavy and slack yarns would cause the Mylar to fail before the yarns could be loaded. Due to the stiffness of the Kevlar yard, normal methods used to straighten the weave pattern proved ineffective. Therefore, it was decided to size the scrim with a 3 percent solution of A-28 adhesive as it was rolled off the loom. This proved very effective and produced a stable and well aligned scrim. The supplier was not equipped to size the scrim, so a tank and roller was jury rigged to size the material. Areas of excessive adhesive were apparent and in places was sufficient to close windows. Properly designed equipment would eliminate the problem.

1.2 BLOCKING TESTS

Because of the areas of excessive adhesive, blocking tests were conducted. No tackiness was observed at ambient temperature. Only one sample (all windows closed) registered a readable value (0.3 lb) at 160°. Test method was Q-41 (sample weighted with 20 lbs for 24 hours at temperature).

1.3 INSPECTION TESTS

Test data from the inspection record are:

(average of 5 tests)

	MD	TD
1.0 inch tensile, lb/in (Q-92)		
Room temperature	156	139
-90°F	149	121
1.0 inch scrim peel (Q-66)	1.8 lb/in	
Laminate weight (sized scrim)	7.603 gm/ft^2 = 2.41 oz/yd^2	
Permeability	0.87 L/M^2/day	

1.4 CREASE EFFECTS

It was found that creasing the laminate significantly degrades the material. Average values for five creased samples (accordion folded tensile specimen creased between thumbnail and forefinger) are 102.0 lb/in for sized scrim and 98.4 lb/in unsized scrim. This is 65% and 63% of the uncreased material. These were MD tests.

For the test spheres, this does not represent a problem. It is of importance for HASPA since the material will be stressed to 60 lb/in. Although funds were not available to conduct an exhaustive test program, limited tests were conducted.

A summary of test results are presented without drawing any conclusions. The intention is to stimulate thinking for further tests. Initial tests made a quick check to determine the effect of jaw separation and crosshead speed.

TEST	DESCRIPTION		RESULTS	
			Break Strength (lb/in)	Percent Elongation
A	Ave. of 5 tests (MD)	control	156	-
	3" jaw x 2"/min CH (crosshead)	creased	102	-
B	2 samples (MD)		160	5.6
	3" jaw x 1.2"/min CH		157	5.6
C	8" jaw x 1.2"/min CH		190	5.1
D	8" jaw x 1.2"/min CH		143	4.1
	zee fold, creased		75% of uncreased	
	failure occurred in the scrim to scrim fold line			
E	380 denier untwisted	control	16.75 lb	4.7
	Kevlar 49 yarn	creased	16.75 lb	4.7
	3" jaw x 0.2"/min			
F	$-90^{\circ}F$, TD sample	control	168	5.5
	2" jaw x 0.2"/min CH	creased	194	6.5
	Creased sample was a zee fold. Failure occurred at the scrim to scrim fold line.			

Notes: All of the tests except F were conducted at room temperature. Test F was the only TD test. The yarn used in Test E was Kevlar 49, whereas the scrim yarn is Kevlar 29.

2.0 CONSTRUCTION

The spheres were fabricated to specification S015700 (Type I) with the following deviations:

1. G1345 substituted for G004701 (scrim out).
2. D026007 (550# nylon line) with the core stripped out for D055400 (Harness lines).
3. End cap installed with a butt seal rather than overlap seal.
4. Tape made from G1345 replaced the T3A0007 tape.
5. Patches for attaching the solar arrays were added to the top end cap.

2.1 SUBSTITUTE HARNESS LINES

Since no flat tubular nylon line (D055400) was in stock, the core was stripped out of 550 lb. line (D026007). The result was a pliable flat tubular line. Average values for five tests were 47 percent elongation and 288 lb. break strength.

2.2 END CAPS

Figure 1 shows the end cap installation. The butt seal end cap design was used to provide good sealability, while maintaining a strong load path between the gores and end cap. It allows a Mylar to Mylar bond by using a continuous ring (made from tape stock) on the inside. A segmented ring (made from G1345 tape stock) was used on the exterior with a scrim to scrim bond. The segmented ring was used because it approximates radial alignment of the scrim.

2.3 KEVLAR SCRIM TAPE

Structural tape was made by coating G1345 laminate with 2.5 mils A-28 adhesive and slitting to 1.5 inch width (adhesive applied to scrim side). Gore seals were made on the traveling sealer. Test seals were made for four

ENGINEERING DEVIATION

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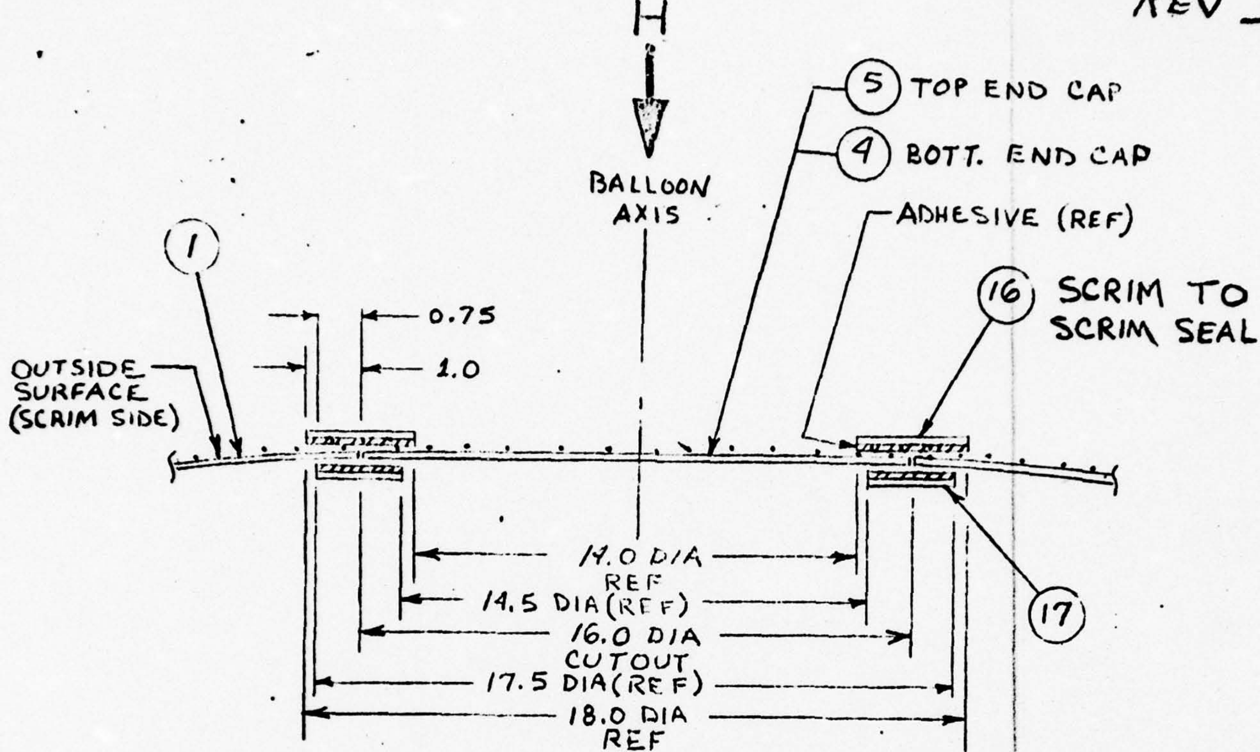
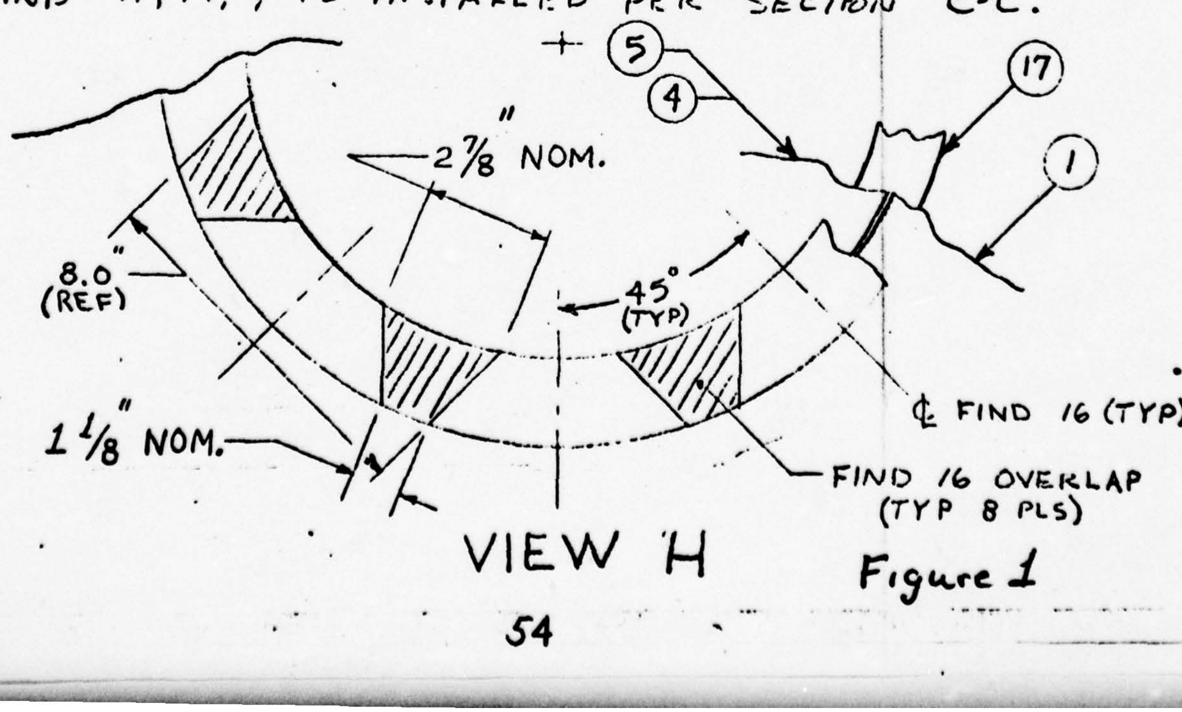
SUPERPRESSURE BALLOON, 11.5 FT DIAMETER DWG 1007538 REV L



SECTION - END CAP INSTALLATION (TOP & BOTT.)
SCALE: NONE

FIND 7, 9, & 10 INSTALLED PER SECTION B-B.

FIND 11, 14, & 15 INSTALLED PER SECTION C-C.



VIEW H

Figure 1

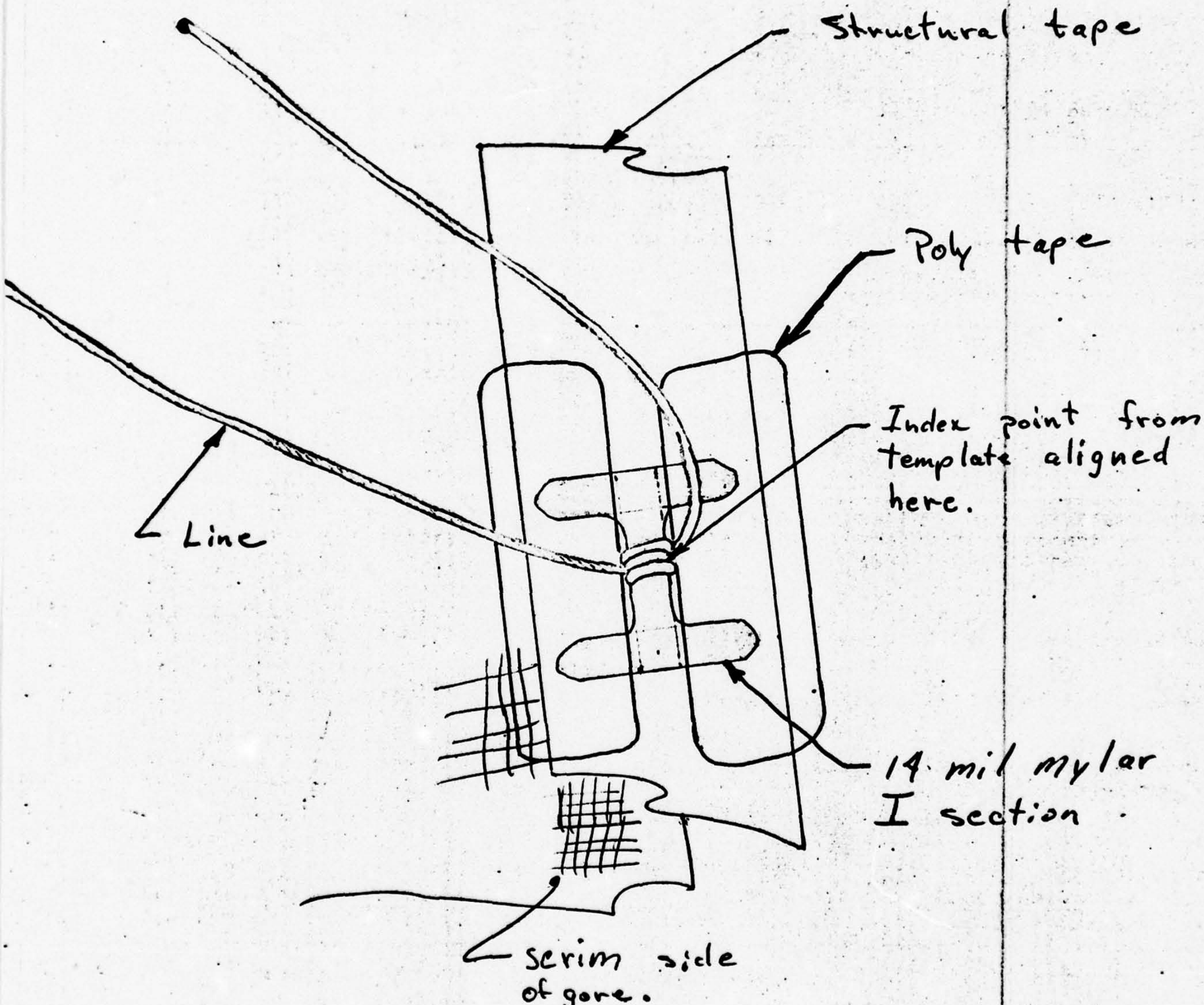
temperatures at five feet per minute. Three tensile specimens were tested at ambient and at -90°F for each test seal (3 inch jaw at 0.2 in/min). One ambient peel test of each tape was conducted on the test seals. Peel test method was Q-66, method A.

Sealing Temperature °F	Average of Ambient	3 Tensiles (lb/in) -90°F	Tape Peel Scrim	(lb/in) Mylar
340	178	196	43	3.6
360	151	175	39	4.5
380	175	167	36	5.0
400	176	181	34	6.0

Based on these tests, gore seals were made at 340° traveling five feet per minute.

2.4 ATTACHMENT OF SOLAR ARRAYS

A sketch of an attachment patch is shown in Figure 2. The line is attached to the I section by means of a clove hitch. This allows some adjustment when installing the arrays. If further adjustment is required, the polytape can be peeled off and the patch relocated. The poly tape does not adhere well to the scrim. Therefore, the patches must be located on the end cap tape or the gore tapes. This was taken into consideration when making the original array templates. One patch was pulled in the instron machine. Fourteen pounds were required to pull the patch off.



Attachment Patch
Full Scale

Figure 2.

3.0 STRAIN MEASUREMENT

Several inflations were required due to a problem encountered with repairing leaks. This presented an opportunity to obtain additional strain information.

3.1 CALCULATED STRAIN

To determine the composite modulus (E_c), it is necessary to obtain the volume ratios of the constituents. It is assumed that the adhesive is equivalent to the Mylar and can be included in the films volume ratio. Volume ratios can be determined by using the density and effective thickness of the constituents. For G1345 material:

Effective film thickness, $t_f = 1.5$ mil

Effective yarn thickness, $t_y = 0.9$ mil

Effective composite thickness, $t_c = 2.4$ mil

Volume ratio yarn, $V_y = 0.377$

Volume ratio film, $V_f = 0.623$

The effective stress in the composite (σ_c) can be determined as:

$$\sigma_c = \frac{\Delta P \ R}{2 \ t_c} \qquad \text{where:}$$

ΔP = Superpressure, psi

R = Radius, inches

Yarn stress can be computed from:

$$\sigma_c t_c = 0.5 \ \sigma_y t_y + t_f \frac{(E_f)}{(E_y)} \ \frac{(\sigma_y)}{(1-\nu_f)}$$

ν_f = Poisson's ratio of the film (0.3)

Film stress is computed from:

$$\sigma_f = \frac{E_f}{E_y} \frac{(\sigma_y)}{(1-\nu_f)}$$

The composite modulus is computed as:

$$E_c = E_y V_y + E_f \frac{(1-V_y)}{(1-\nu_f)}$$

Based on weight estimates, the balloons will float at 156 mb.

assuming:

14% free lift

+ 10% supertemperature

$E_y = 8.74 \times 10^6$

$E_f = 0.6 \times 10^6$

the following values are obtained.

$E_c = 3.82 \times 10^6$ psi

$\sigma_c = 8{,}247$ psi

$\sigma_y = 33{,}000$ psi

$\sigma_f = 3240$ psi

strain $= 2.2 \times 10^{-3}$ in/in

The percent strain at a differential pressure of 25.0 inches of water is 0.34%.

3.2 STRAIN FROM INFLATION TESTS

Strain information was obtained from a 36 inch gage (Shel-meter type) and by measuring the balloon diameter on gore centerline and on a gore seal. The balloons are identified as number 1 and 2, and are marked on the inflation handles.

Two inflations were made for balloon No. 2. Percent strain, based on the 36 inch gage, is presented in Figure 3. In addition, three points were measured during deflation to measure any permanent deformations. Figure 4 presents percent strain as determined from diameter measurements during the first inflation. Figure 5 shows the percent strain, based on the 36 inch gage, for balloon No. 1. The same scales were used and the figures can be compared directly. Raw data are recorded in lab notebook 528 (p.21-23).

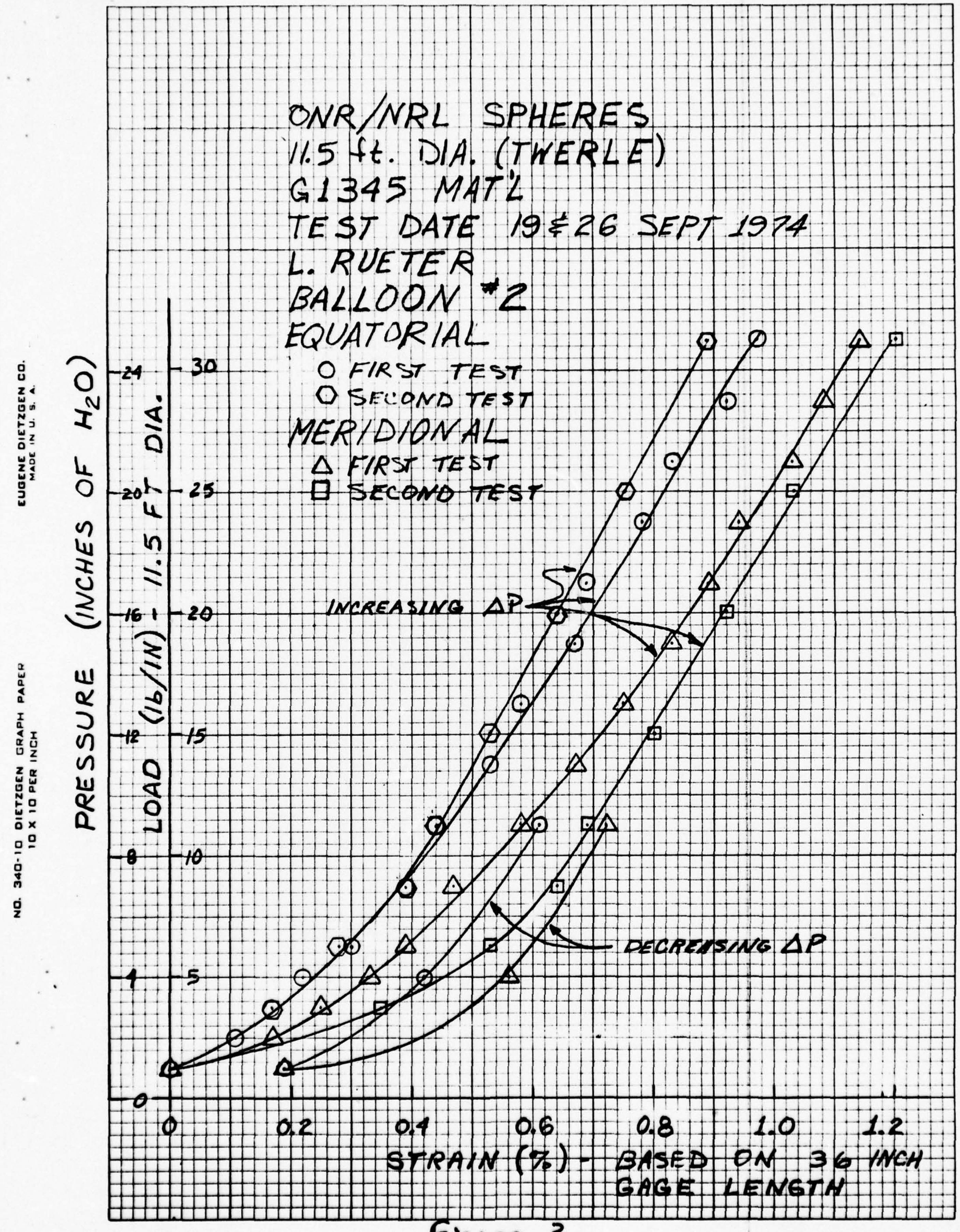

ONR/NRL SPHERES
11.5 ft. DIA. (TWERLE)
G1345 MAT'L
TEST DATE 19 & 26 SEPT 1974
L. RUETER
BALLOON #2
EQUATORIAL
○ FIRST TEST
⬡ SECOND TEST
MERIDIONAL
△ FIRST TEST
□ SECOND TEST
INCREASING ΔP
DECREASING ΔP
PRESSURE (INCHES OF H_2O)
LOAD (lb/IN) 11.5 FT DIA.
0
4
8
12
16
20
24
5
10
15
20
25
30
0
0.2
0.4
0.6
0.8
1.0
1.2
STRAIN (%) - BASED ON 36 INCH GAGE LENGTH
NO. 340-10 DIETZGEN GRAPH PAPER 10 X 10 PER INCH
EUGENE DIETZGEN CO. MADE IN U. S. A.

Figure 3

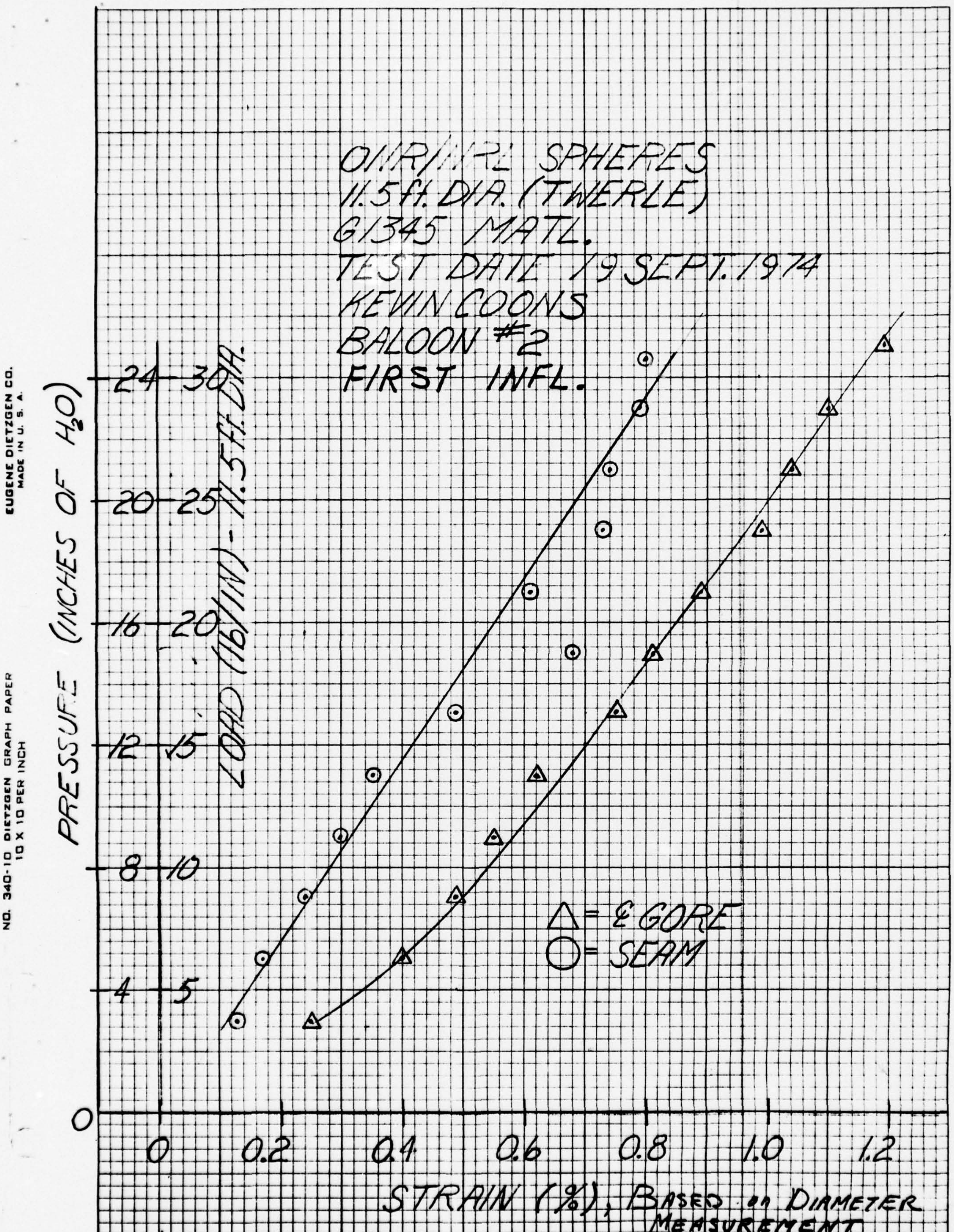

ONR/NRL SPHERES
11.5 ft. DIA. (TWERLE)
G1345 MATL.
TEST DATE 19 SEPT. 1974
KEVIN COONS
BALOON #2
FIRST INFL.
PRESSURE (INCHES OF H2O)
LOAD (lb/IN) - 11.5 ft. DIA.
△ = ℄ GORE
○ = SEAM
STRAIN (%), BASED on DIAMETER MEASUREMENT
0
0.2
0.4
0.6
0.8
1.0
1.2
4
8
12
16
20
24
5
10
15
20
25
30
NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

Figure 4

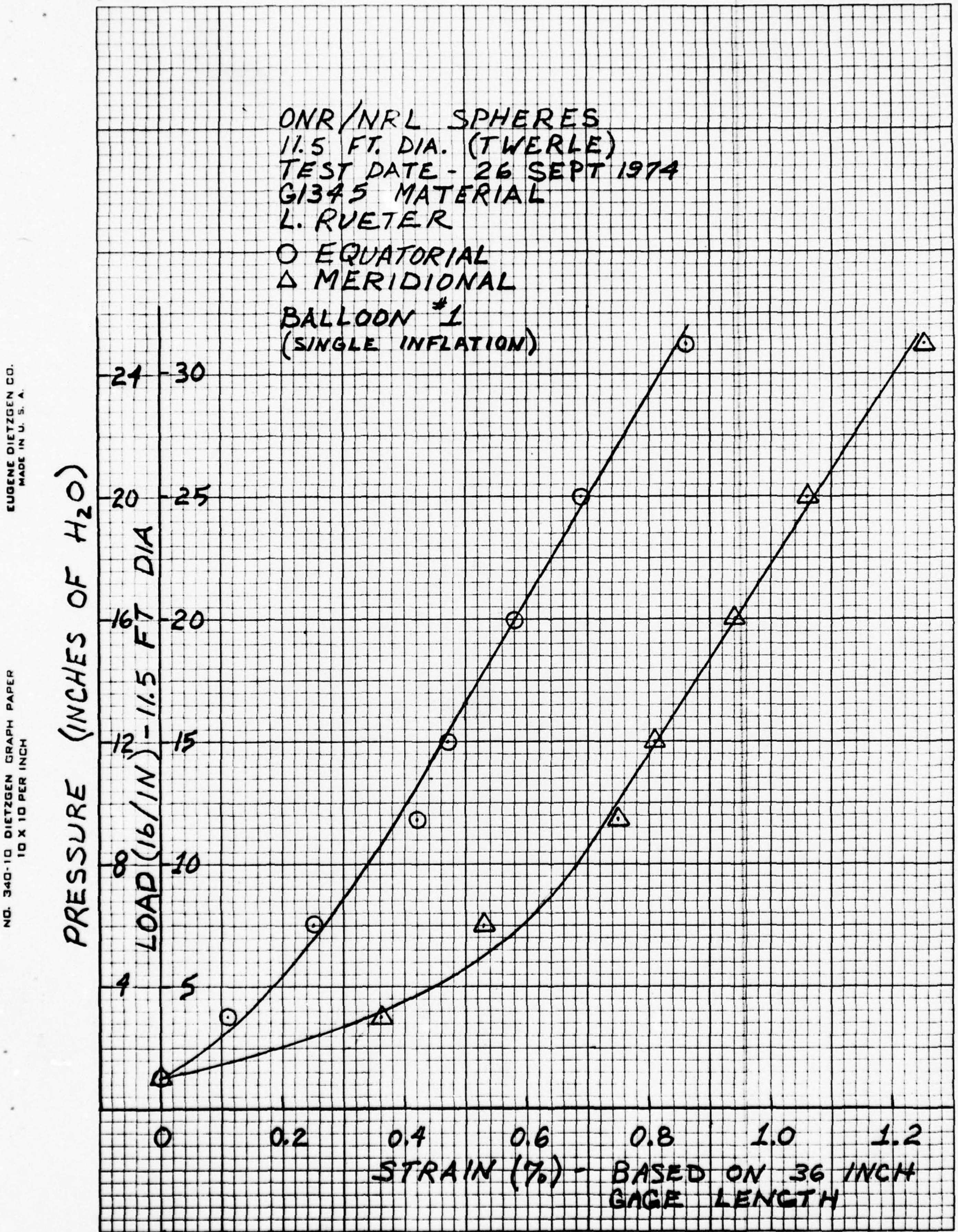

ONR/NRL SPHERES
11.5 FT. DIA. (TWERLE)
TEST DATE - 26 SEPT 1974
G1345 MATERIAL
L. RUETER
O EQUATORIAL
Δ MERIDIONAL
BALLOON #1
(SINGLE INFLATION)
PRESSURE (INCHES OF H_2O)
LOAD (lb/IN) - 11.5 FT DIA
4
8
12
16
20
24
5
10
15
20
25
30
0
0.2
0.4
0.6
0.8
1.0
1.2
STRAIN (%) - BASED ON 36 INCH GAGE LENGTH
NO. 340-10 DIETZGEN GRAPH PAPER 10 X 10 PER INCH
EUGENE DIETZGEN CO. MADE IN U. S. A.

Figure 5

4.0 LEAK REPAIR

It was found that normal techniques of repair for superpressure balloons could not be used on the Kevlar spheres. This was due to the scrim being on the outside. Test repairs of 0.04 mm (0.0016 in.) diameter holes were made on G1345 diaphragms. Tests included: RTV, 5 minute epoxy, painting with A-28, and A-28 with poly tape. An effective repair could be made with either the epoxy or A-28. Since the A-28 repair was more pliable, painting with A-28 was selected as the repair method. Small holes, .04 mm could be repaired at 16 inches of water pressure. Holes as large as a complete window could be repaired at zero pressure. It was decided to mark the holes detected at 16 inches of water, deflate to one inch of water, and then paint the holes. In this manner, the certainty of the repair was improved while maintaining the shape until the adhesive dried.

A total of 8 holes were repaired on balloon No. 1. Three holes (closely spaced) appeared to be a result of blocking. They did not occur in an area of excess adhesive. Five holes were repaired on balloon No. 2. The majority of the holes appeared along or near yarns and were not visible. Holes that were visible, except the three discussed previously, appeared to be a result of handling. In addition, the end cap seals were painted on balloon No. 1. It was not ascertained why the end caps of one balloon leaked and not the other. (Leak repair tests are recorded in lab notebook 509, p.32-33).

5.0 PACKING AND SHIPPING

The balloons were shipped in a wood box approximately 24" x 48" x 18" (inside dimensions). A divider, fully supported from top and bottom, separated the balloons. Each balloon was folded to one gore width, end cap pads installed, and then sealed in a 36" poly sleeve. Lengthwise folds were then made with foam logs at the fold line. Each folded balloon was then placed in an envelope of vapor barrier material and sealed. Additional protection was furnished by lining each half of the box with bubble-poly.

Note: each balloon weighed 4181 gms as measured by a solution ballance.

END FITTING REPORT (OUTLINE I)

1. Introduction

2. Requirements

3. Previous Designs

4. Alternative Designs

5. Recommended Designs

Requirements

1) Transfer individual load from Poly Plus to Fitting

2) Seal balloon ends

3) Minimum cost--Cheap material; Simple to fabricate; Simple to install

4) Provide mounting surface for valve(s), instruments, etc.

5) Provide mechanical link to payload train.

Assumptions

Natural shape balloons--load at base

End Section form of balloon--cylinder, TT, tailored

Requirements

Primary
Transfer suspended point load into individual stree field of balloon fabrics
Provide gas tight closure of balloon ends (flow rate $<$ 1cc/sec)
At minimum cost--material, fabric, installation

Secondary
Provide mounting surface for valves, instruments, cable connectors, etc.

Assumptions

Natural shape balloon - load at base

End section forms

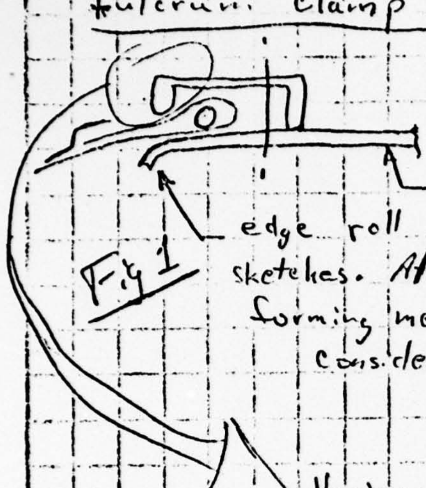
Safety factors--$\sim$6:1 on soft material
5:1 on hardware

TITLE Poly + Balloon Design

PROJECT NO. 10203-05
BOOK NO. 528

Top End Fty.
Fulcrum clamp & seal

Red – Poly + material
Black – Hardware
Blue – Sealing material

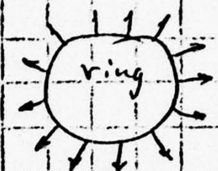


Alm. plate (Typ)

edge roll varies with sketches. Alternate types & forming methods to be considered.

Fig 1

Tension loads carried in ring – clamp only serves as locator & seal



Various edges – extruded (channel) formed

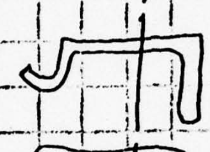
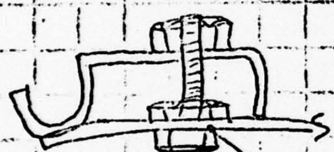


Fig. 2

Bolts could be installed and sealed – fulcrum attaches as chevy rocker arms. – (Fig. 3)



Sealed prior to end cap installation.

Fig 3

Double Ring

interference of double ring clamps Mat'l – Principle of D Buckles

leads to

Fig 4

Requires preload in material to clamp rings down.

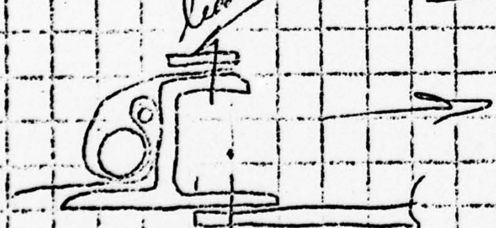
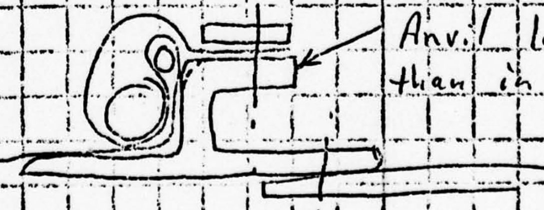
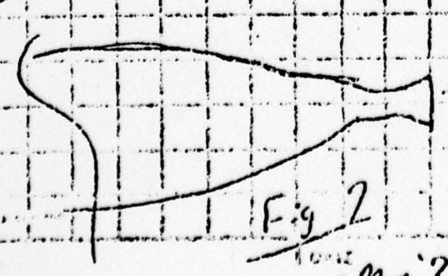


Fig 5



Anvil lower than in Fig. 5

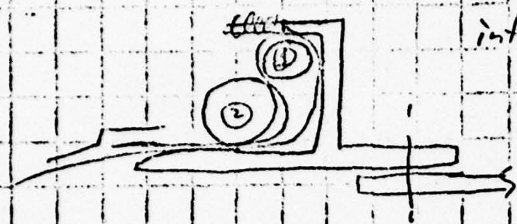
Fig 6



All ring types should use "taylored" gores for best load distribution – Cylinder Section in area of ring.

Fig 2

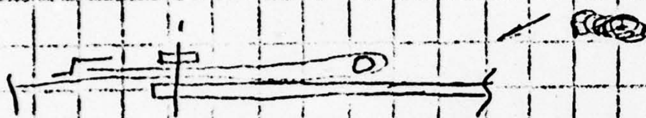
13 May '74



interference in all directions

①&②
Ring must disassemble

Poor Fig:

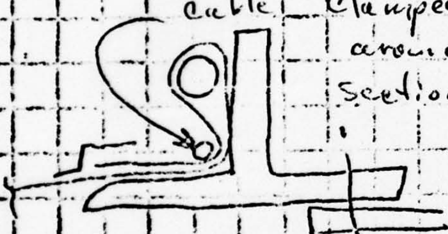


Simplest to make
Mat'l preloaded before clamping

Figure 9

Could use this with interference rings. Not ~~so~~ sure there would be any benefit - May pick up load beter

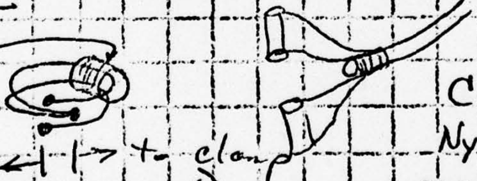
cable clamped around section - "Voss" clamp



Use covered cable - Urethane jacket or "Nolero" tether

Figure 10

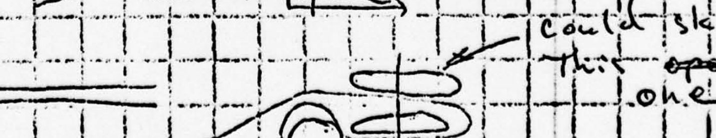
Cables inside clamping Jacket.



↔ to clamp

Could also use Nylon line - Much as one would whip a rope - with or w/o ring

Could skip this ~~open~~ one

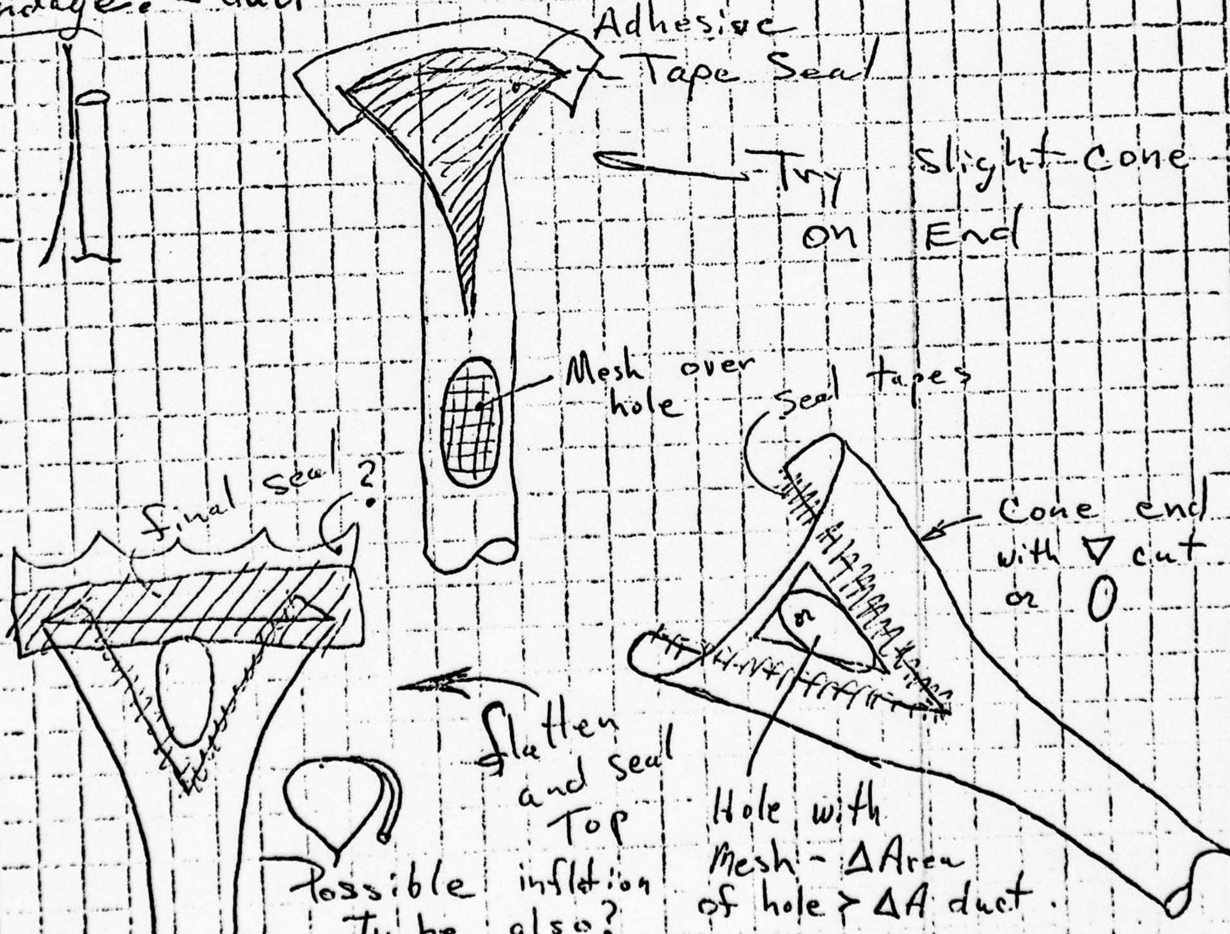


Poly +, Balloon Design

102.03
528

Inflation Ftg

Appendage: - duct



13 May '74

1

Prev Designs

Loop Seal

Wedge Collar - w + w/o band

Clamped - snubber ring

Material bulk - determine min dia of filtering

Matl distribution - uniformity

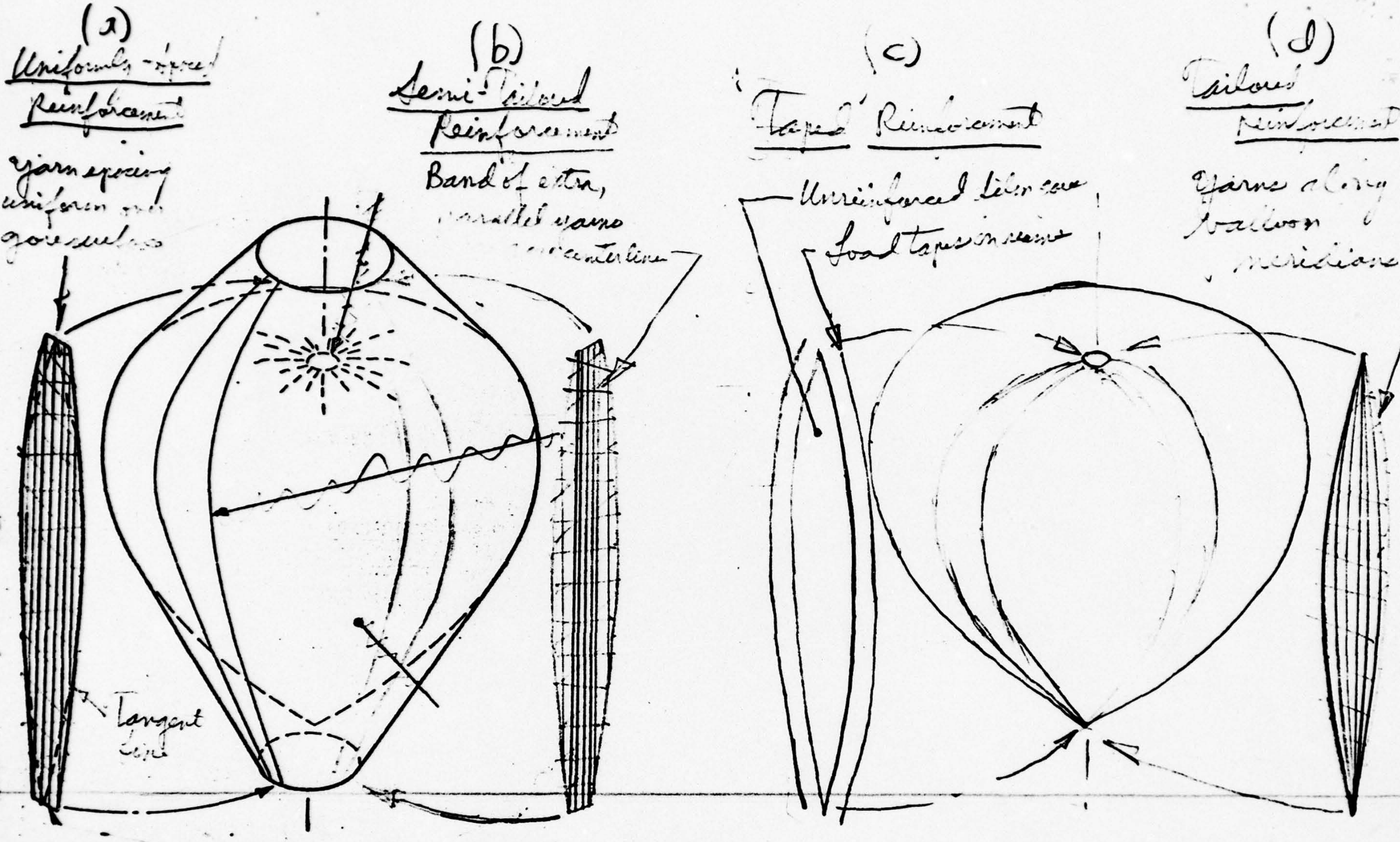
(pleating)

End[illegible] termination

tailored
cylindrical
taper tangent

$$\frac{T}{N} = f \qquad T_1 = T_2 e^{\alpha f}$$

$$Nf = \qquad N = T_2 e^{\alpha f}/f$$



Taper Tangent End Sections
~~(Reinforced Mylar Balloon)~~

Fully Tailored End Sections
~~(Reinforced Polyethylene Balloon)~~

Figure —: End Section Design Practice Natural Shape Balloon

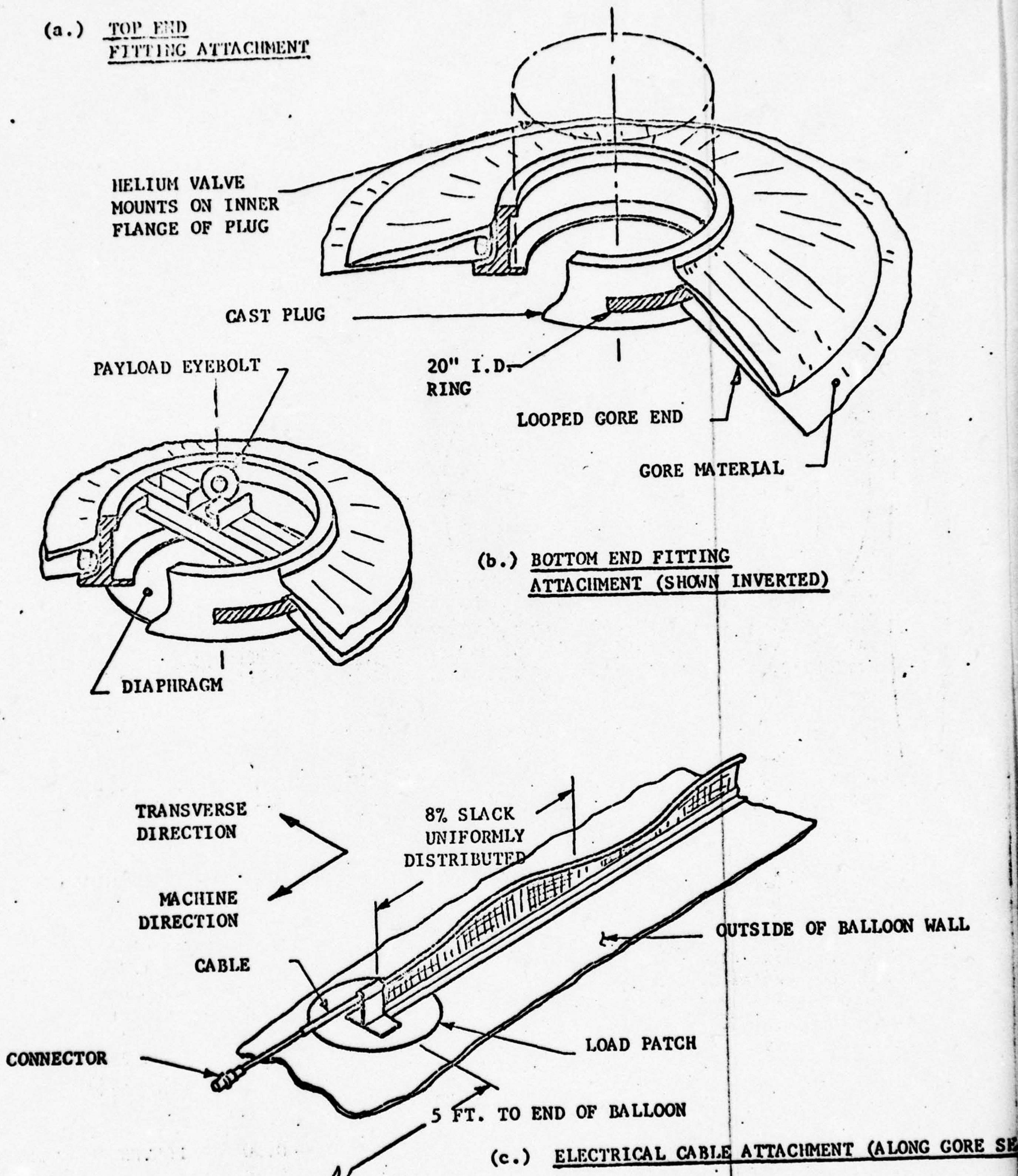
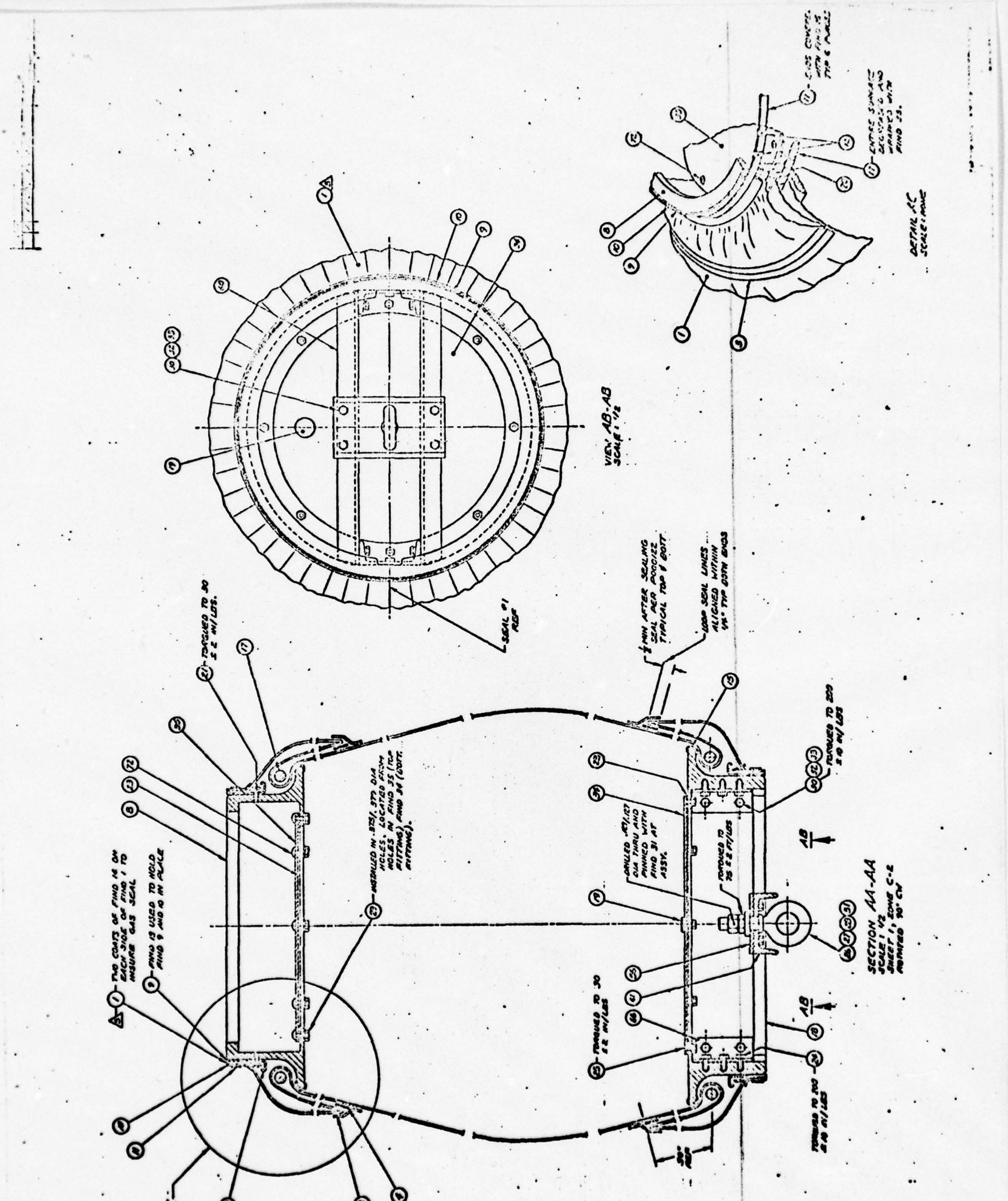


FIGURE 3:

TYPICAL HARDWARE ATTACHMENTS


SECTION AA-AA
VIEW AB-AB
DETAIL AC

INSTALLATION OF LOOP SEAL END FITTINGS

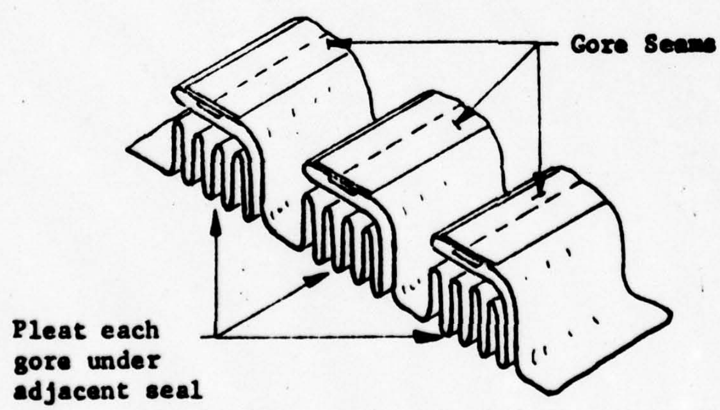
REV.	ECO	CHANGED

6.4 Make the final gore seam in balloon through the gas seal skirt, and 6 feet down from the loop seal around the loop.

7. PLEATING OF MATERIAL IN LOOP

7.1 Hang the material ring with balloon end loop installed on padded core in installation jig. Orient material so that half of the material is on each side of core (use seal numbers). Cover the part of the balloon on the table near the installation jig with padded blankets to prevent damage to the balloon fabric.

7.2 Gather the fabric in one gore width in folds and place the adjoining seal on top of the folds as shown below. The number of folds required will depend on the gore width. Secure the pleated material with masking tape.



Cross-Section Through Pleated Loop

7.3 Distribute the pleated material evenly around the fitting using the seal numbers for reference. For example, in a balloon having 100 seals, seal 25 should be at 90° from seal 1, seal 50 at 180 degrees, seal 75 at 270°, etc.

5.3.2 Duct Elliptical Opening - Each duct opening in the balloon wall shall have an elliptical shape characterized by a ratio (major diameter to minor diameter), of 2/1. This opening shall be so oriented as to make the major axis of the ellipse coincide with the respective balloon gore seam within 1/8 inch.

5.3.3 Duct Heat Seals - The heat seals used in making a duct assembly and joining a duct to the balloon wall around the elliptical opening shall conform to section 5.1.1 of this specification. The heat seals used to join a duct to a balloon gore seam hem may be intermittent, with unsealed lengths not exceeding 1/2 inch. All tucks in the duct, required to compensate for balloon curvature, shall be heat sealed to the balloon gore seam hem.

5.4 Inflation Tube - Inflation tubes shall be constructed from uncolored, 20 inch layflat tubing. Inflation tube apertures shall be circular in shape and each inflation tube shall terminate in a gas diffuser, inside the balloon. The external portion of each inflation tube shall be accordion folded and placed in a red polyethylene bag.

5.4.1 Inflation Tube Attachment - Each inflation tube shall be joined at its aperture in the balloon wall by a heat seal, conforming to section 5.1.1 of this specification. This attachment shall be reinforced to preclude stressing of the heat seal under normal inflation conditions.

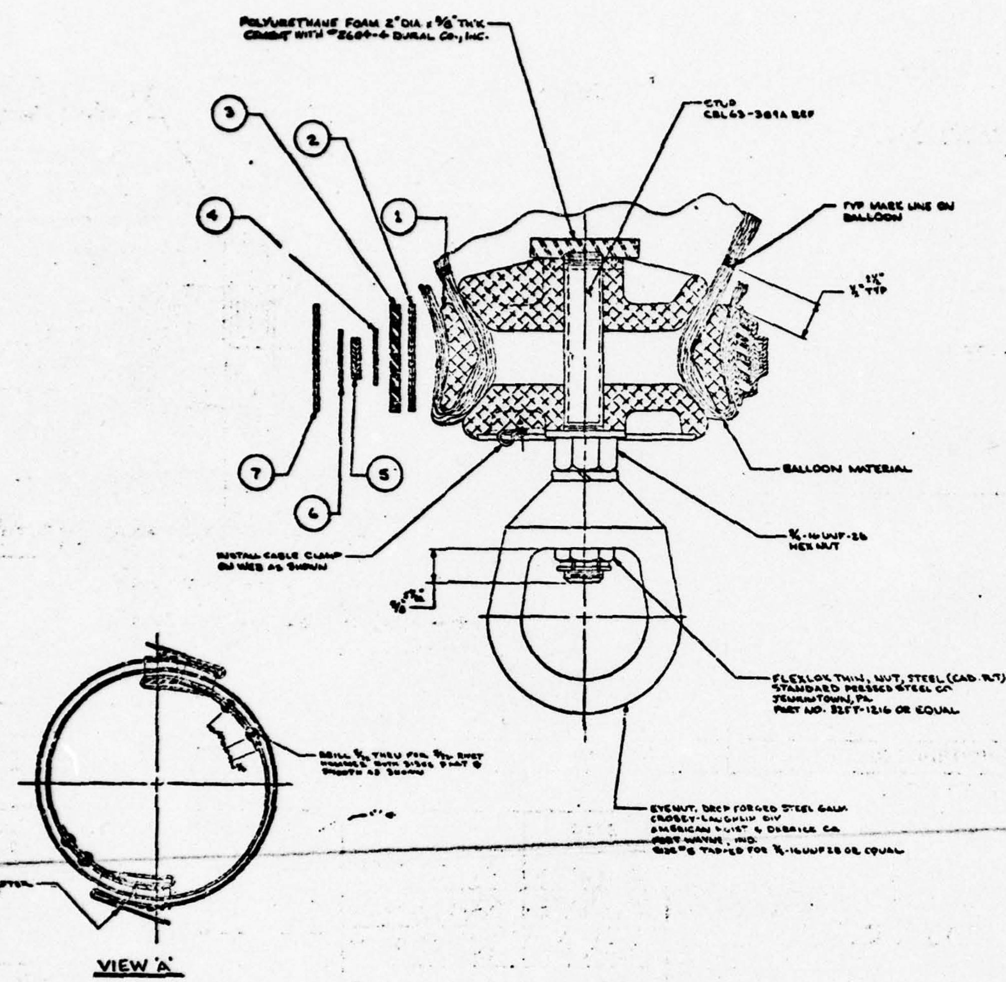
5.5 End Fittings

5.5.1 Bottom End Fitting

5.5.1.1 Taped Balloons - The bottom end fitting shall be a banded wedge-collar. Installation of this fitting shall be in accordance with drawing number CRL-67996D.

5.5.1.2 Tapeless Balloons - The bottom end fitting shall be a wedge-collar type in accordance with drawing number CRL-63387C. Installation of this fitting shall be in accordance with drawing CRL-67996D or CRL-67997D.

5.5.2 Valve Top End Fitting - The top end fitting shall be constructed and installed in accordance with drawings CRL-63634D, CRL-63635D and CRL-63636B, except when the tops of the gores are specified to be fully tailored. In the latter case, the apex fitting shall be an approved assembly identical (in all essential aspects) to that depicted in drawing number CRL-64445D.



A REVISED ITEMS 2,6,7 [illegible]

NOTES:

1. STACKING PROCEDURES MUST BE ESTABLISHED TO INSURE EQUAL DISTRIBUTION OF BALLOON MATERIAL IN FITTING
2. WRAP COMPLETE ASSY SUFFICIENTLY WITH POLY TAPE ELIMINATING ALL SHARP PROJECTIONS & CORNSTARCH.
3. BAND (ITEM 5) TO BE DOUBLE WRAPPED & DOUBLE CLAMPED PER VIEW 'A'
4. TORQUE BAND TO 95±5 INCH LBS WITH TORQUE WRENCH
5. CUT STUD CEL63-389A TO PROPER LENGTH AFTER FINAL TORQUING (REF)

ITEM	QTY	DESCRIPTION
7	A/R	TAPE #303 [illegible] WIDE 1 LAYER
6	A/R	TAPE #890 2" WIDE 1 LAYER
5	A/R	BAND "BAND IT" 2 LAYERS [illegible]
4	A/R	TAPE #890 [illegible] WIDE 1 LAYER
3	A/R	FELT [illegible] THICK 2" WIDE 1 LAYER
2	A/R	TAPE #397 [illegible] 2" WIDE 2 LAYER POLY
1	A/R	6 TO 10 MIL POLY COVER [illegible] OR EQUAL

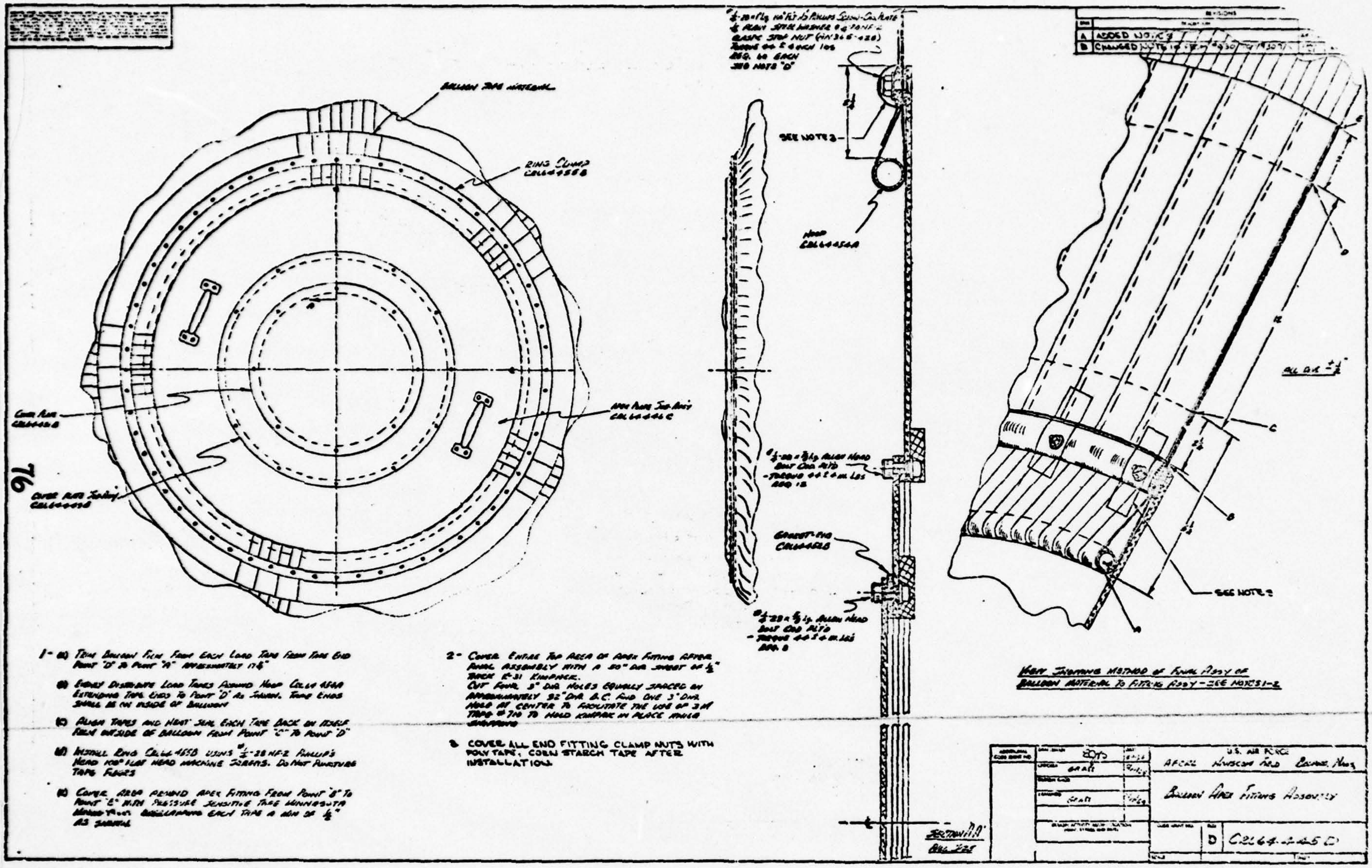
LIST OF MATERIAL

BOTTOM STANDARD END FITTING ASSY TAPE & BANDED

AIR FORCE CAMBRIDGE RESEARCH LAB L.G. HANSCOM FIELD BEDFORD, MASS.

CEL 67-[illegible]D

SCALE FULL


Balloon Tape Material
Ring Clamp
Cover Plate
Apex Plate Sub-Assy
See Note 3
Hoop
Gasket
Section "A-A"
See Note 2
View Showing Method of Final Assy of Balloon Material to Fitting Assy - See Notes 1-2
1- (a) Trim Balloon Film From Each Load Tape From Tape End Point "D" To Point "A" Approximately 17½"
(b) Evenly Distribute Load Tapes Around Hoop Extending Tape Ends To Point "D" As Shown. Tape Ends Shall Be On Inside of Balloon
(c) Align Tapes and Heat Seal Each Tape Back on Itself From Outside of Balloon From Point "C" To Point "D"
(d) Install Ring Using ¼-28 NF-2 Phillip's Head 100° Flat Head Machine Screws. Do Not Puncture Tape Fibers
(e) Cover Area Around Apex Fitting From Point "B" To Point "E" With Pressure Sensitive Tape Minnesota Mining... Overlapping Each Tape a Min of ½" As Shown
2- Cover Entire Top Area of Apex Fitting After Final Assembly With a 50" Dia Sheet of ½" Thick K-31 Kimpack.
Cut Four 3" Dia Holes Equally Spaced on Approximately 32" Dia B.C. And One 3" Dia Hole at Center To Facilitate The Use of 3M Tape #710 To Hold Kimpak in Place While Shipping
3 COVER ALL END FITTING CLAMP NUTS WITH POLY TAPE, CORN STARCH TAPE AFTER INSTALLATION.
U.S. AIR FORCE
AFCRL Hanscom Field Bedford, Mass
Balloon Apex Fitting Assembly
D
C2264-445 D
Revisions
A Added Notes
B Changed Notes
76

XV. Problems Encountered in the Development of the Stratoscope II Flight System

G.C. Ellerton, Jr., and J.P. Jackson
Vitro Laboratories
Silver Spring, Maryland

Abstract

The balloon development phase of the Stratoscope II Program began in the Fall of 1960. At that time, the design of the telescope was, for all practical purposes, complete and fabrication was in progress. Flight system requirements were established with certain limitations imposed by the instrument design. It was immediately obvious that Stratoscope II requirements were pushing the state-of-the-art in ballooning and that some pioneering in the development of heavy-load high-altitude techniques would be necessary. The principle problems encountered during the balloon development phase were related to and grew out of the sensitivity of the Stratoscope II telescope to ground handling, launching and recovery shocks; the requirement for a night flight; the unprecedented weight of the payload; the need for a reasonable standby time when the system was flight ready; and, the need for a single all-year-round launching site. Problems were approached and solved during a period of analysis, design, fabrication, laboratory and actual full-scale field tests culminating in a fully instrumented scientific flight in March of 1963. Since that time, the flight system has been under continuous review and modification to improve its reliability.

6

5. PROBLEMS RESULTING FROM THE UNPRECEDENTED WEIGHT OF THE PAYLOAD

5.1 Balloon Design

At the outset of the program it was realized that the gross lift of this system would far exceed that of any previous high-altitude plastic balloon. Although polyethylene balloons of a size that would contain the required helium had been successfully flown to high altitudes, this material had not been proven in the really heavy load area. Therefore, a search for other balloon fabrics was initiated. Of all the various materials investigated, the G. T. Schjeldahl Company's laminate of mylar film and dacron scrim seemed to hold the most promise. This material has proven itself capable of handling the heavy Stratoscope II loads with high reliability. Problems encountered in the balloon development phase were never associated with a failure of the material itself. Problems encountered were associated more with the manner in which the material was secured in the balloon fittings and in the operational techniques of inflation. Some of the interesting problems encountered in the development phase of the balloon design are discussed in the following:

5.1.1 END FITTINGS

It was discovered early in the program that conventional fittings would not utilize the full strength capable of the scrim/mylar fabric. A redesign of the fittings to eliminate weak points was accomplished after a flight attempt failed because of material tearing away at the top fitting. A technique for attaching the balloon fabric to a hoop at each end of the balloon proved very successful. The hoop to which the material was attached was in turn held in a top or bottom fitting of more conventional design. Figure 5 is a sketch of the loop-seal method of securing balloon fabric to the end fittings. Tests to check the capability of this attachment procedure indicated very little loss of fabric strength at the end fittings.

5.1.2 SEALING OF SCRIM MATERIAL

The sealing of scrim material presented a problem in that it was difficult to prevent passage of helium around and through the actual scrim fibers w n the scrim material was lapped at the joints. This problem was solved by butting the gore edges together with a plain no-scrim mylar tape secured to the smooth side of the balloon material for gas seal. On the outside of the seal where the gore edges butted together a scrim/mylar tape was secured to provide the strength bond between gores. This bi-tape seal technique solved the problem of helium leakage.

5.1.3 MULTIPLE INFLATION TUBES

The heavy weight of the payload and the associated balloon system meant a large volume of helium for initial inflation. To reduce the inflation time the balloon was

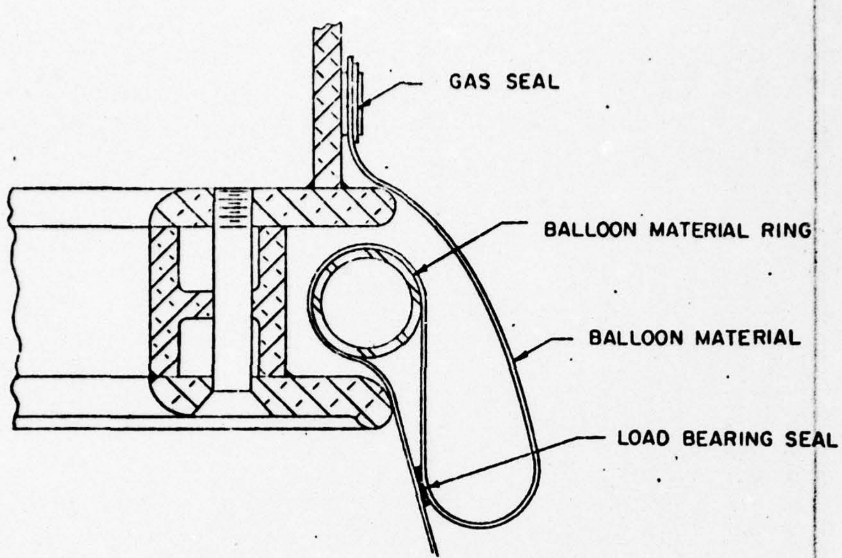


Figure 5. Loop-Seal End Fitting

designed with four inflation tubes. These inflation tubes were designed to pass helium from the high-pressure hoses to the balloon at the maximum rate available from the helium tanks.

5.2 Ballast Limitation

As the program progressed, the weight of the telescope increased. To keep the overall system weight to a practical minimum, we made every attempt to limit the ballast requirements. After the balloon system design was firm, the telescope increased further in its weight and this limited even more the quantity of ballast that could be carried. The problem was one of minimizing the need for ballast. The elimination of sunset ballast by launching just before sunset has been discussed in previous sections of this paper. The quantity of ballast for optimum control of the balloon system during the latter phases of its descent was estimated to be about 2500 lb at the beginning of the program. This weight of ballast was considered minimum for useful control of the balloon in selecting a desirable impact area. However, to further reduce the weight of ballast carried, it was decided to allow the balloon to descend continuously from ceiling to ground without pausing at some intermediate altitude for selection of a landing site. The present operational technique is to valve enough helium to attain an initial descent rate of 300 ft/min which increases to approximately 750 ft/min upon penetration of the tropopause without further valving. The ballast is used to adjust the final impact descent rate to

and heat and pressure were applied. When the balloon deployed during inflation and ascent, the tape unfolded and the seam assumed the attributes of a conventional taped butt-joint (Figure 2).

5.3 CYLINDER TEST BALLOONS

One 5-gore cylinder balloon, 40 feet long and 5.92 feet in diameter, was fabricated from the GT-98 material laminated under Item I of the work statement. Seal tapes were made of thread reinforced GT-300 tape. This cylinder was fitted with inflation and pressure taps while the ends were pleated and tied around a wooden spool.

On the first attempt at a superpressure burst test using air, one end of the cylinder slipped off the spool and opened at a pressure of 2.4 inches of water. This was reassembled and sealed shut into a pillow end for second test attempt. At 3.8 inches of water the opposite end blew open. This was also sealed into a pillow end and the test repeated for a third time. On the third attempt the cylinder was pressurized to 4.2 inches of water and burst. Failure consisted of a longitudinal tear from end to end but not crossing any seal.

Applying the cylinder burst formula of $S = Pr$ the skin stress at burst pressure was found to be 5.52 lbs/in. This value was very close to the value previously obtained at room temperature for the material and seals.

5.4 DESIGN AND TESTING OF FITTINGS

A fitting test was conducted using a 40-gore cylinder balloon 20 feet long. Total material in the end section was 1440 inches, which simulated a 144-gore balloon with 10-inch gore end sections. Two 6-inch diameter, triple banded, spool end fittings were installed and tension applied to each end of

the simulated balloon.

The load was applied in approximately 1000 pound increments with a 15-minute hold at each loading. The material failed approximately 1 foot from one fitting at 4000 pounds. Applying a straight tensile load formula to this test the loading at rupture was found to be 2.68 lbs/in.

After observing the ruptured material, it was concluded that unsymmetrical loading due to uneven pleating caused a stress concentration in the section which resulted in a premature failure of the material. In order to compensate for this, as well as to use the experience from a banded end fitting failure on a reinforced Mylar balloon fabricated under AF 19(628)-4179, it was agreed that another test would be required using a standard loop seal gore termination. Loop seal fittings had been used on all previous AFCRL Mylar reinforced balloons with complete success.

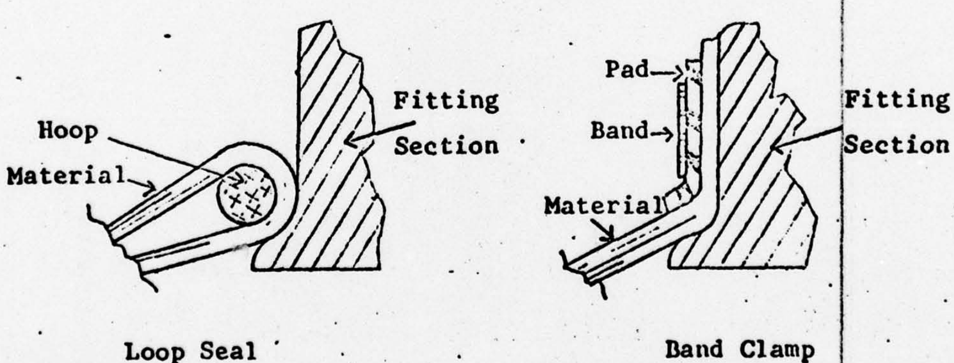


Figure 3

A 10-foot diameter superpressure "onion" balloon using two 18-inch diameter fittings was selected as the best method to test gore end section termination.

The 10-foot diameter onion balloon having a cast magnesium loop seal end

fitting was inflated and observed to burst at a pressure of 4 inches of water. The theoretical skin stress associated with this pressure was 4.33 pounds/inch.

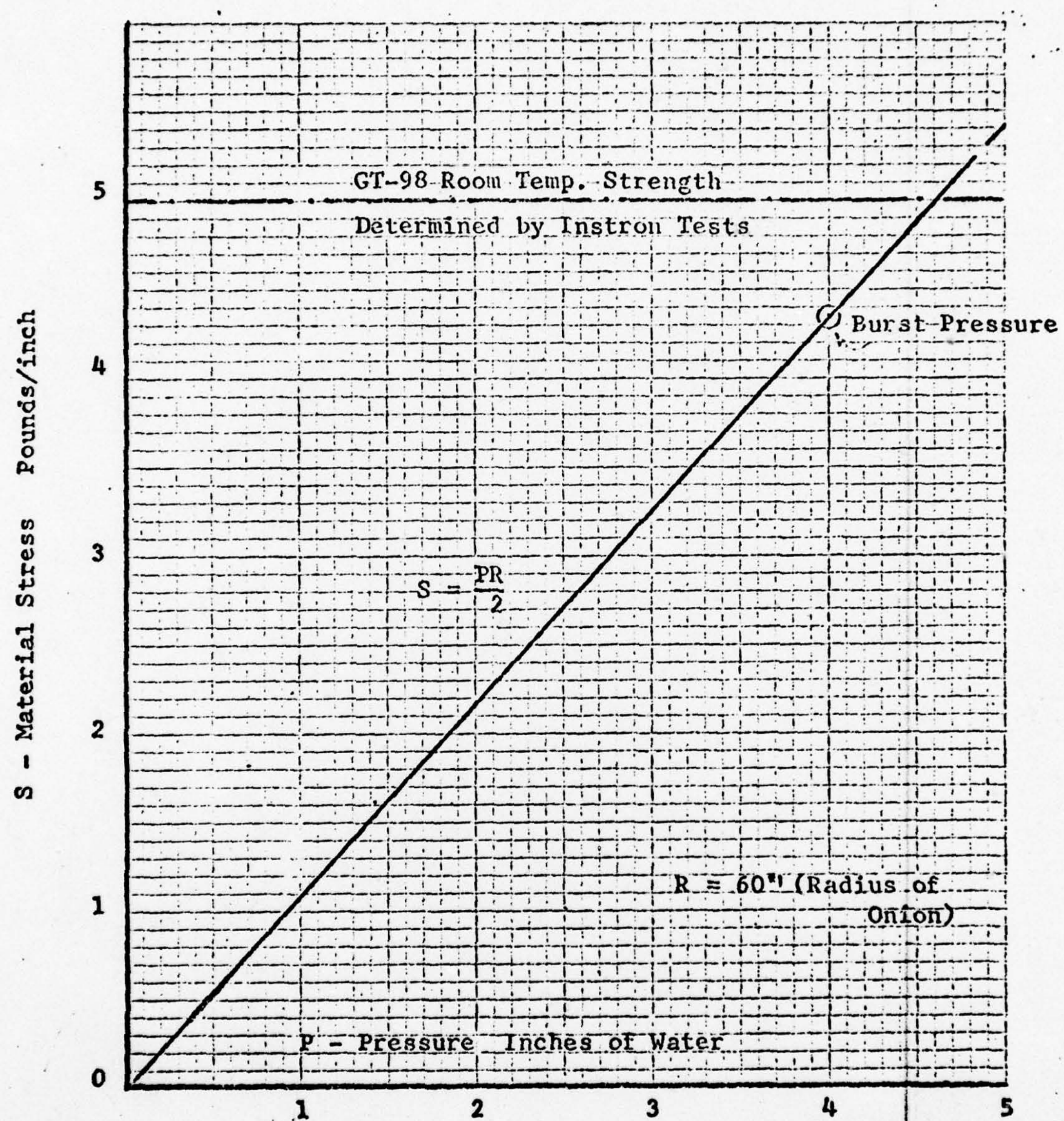
The attached graph (Figure 4) represents the theoretical material stress as a function of balloon pressurization. The sphere stress equation, $S = Pr/2$, was used to construct the graph. The graph also shows the GT-98 material strength, 5.0 lbs/in, as determined by Instron tensile tests at room temperature. The material stress of the balloon approximated this value before rupture.

The rupture location was in the bottom end fitting loop seal area. The initial break was above and adjacent to the loop seal in a single layer of material. The rupture continued above the loop seal for a distance of 50 inches, crossed one seam and terminated at the next. One end of the break turned at a seam and tore the length of the gore to the top loop seal area.

The test indicated satisfactory material integrity and construction techniques throughout the sphere system, and it was concluded that GT-98 was adaptable to the loop seal technique of material restraint.

To test the fitting design, an 18-inch diameter bottom fitting was fitted with a GT-12 loop seal load member, and a load of 3000 pounds applied at the attachment point on the load beam. The cast magnesium ring distorted approximately 1/4 inch. When the load was removed, however, the casting regained its original shape. As the payload was not to exceed 300 pounds, it was concluded that the fitting was adequate. The load beam attachment should be redesigned to better distribute the weight around the circumference of the casting to increase the load capacity of the fitting for future applications.

After stressing the system in the above test, the loads were relaxed and



SKIN STRESS VS PRESSURE FOR TEN FOOT DIAMETER ONION SPHERE

Figure 4

As a result, it was concluded that the mainstay lug lacked sufficient strength in the shackle attachment area. As a means of correcting the weakness, a steel reinforcement was designed, doubling the yield strength of the lug. The redesigned mainstay lug was incorporated into the transfer duct and its tensile strength tested in exactly the same manner as the previous design. No permanent strain was induced in either the mainstay lug or in other components of the system; it was concluded that the system possessed sufficient structural strength.

5.5 BULK FACTOR TEST

A simulated gore-end, bulk factor, tensile test was conducted to determine whether the bulk pleating of material on the loop seal hoop had any detrimental effect on the strength of the loop seal. On the full scale balloon the bulk of material would be distributed around the 18-inch diameter balloon material ring at the rate of approximately 32 inches of material per inch.

A 62-1/2-inch wide strip of GT-98 was forced into a loop seal around a 3/8-inch diameter material retainer ring and pulled to rupture. A dynamometer was used to record rupture loads. The sample failed at a tensile load of 125 pounds; theoretical rupture strength of the sample is 312 pounds (62-1/2-inch wide sample of strength 5.0 pounds/inch).

The type of failure was not tensile rupture but due to a tear initiated in the rough edges in the middle of the material sample. Therefore, it was concluded that the test was not valid. The separated material was rejoined by tying the two ends in a square knot with the knot tied above the loop seal, thereby including the double layer of material in the loop seal area. This configuration was pull tested and failed at 320 pounds. This failure was tear

initiated on the material edges, but it did not indicate any weakness of the material in the area wrapped around the 3/8-inch diameter grommet. It was concluded that this second test was valid as it showed that stacking and pleating of material on the grommet (bulk factor) did not result in any weakness at this point, and that the strength of the material gathered on the grommet is equal to the theoretical strength of the gore material.

Construction details for onion shaped, superpressure balloon with tailored reinforcement.

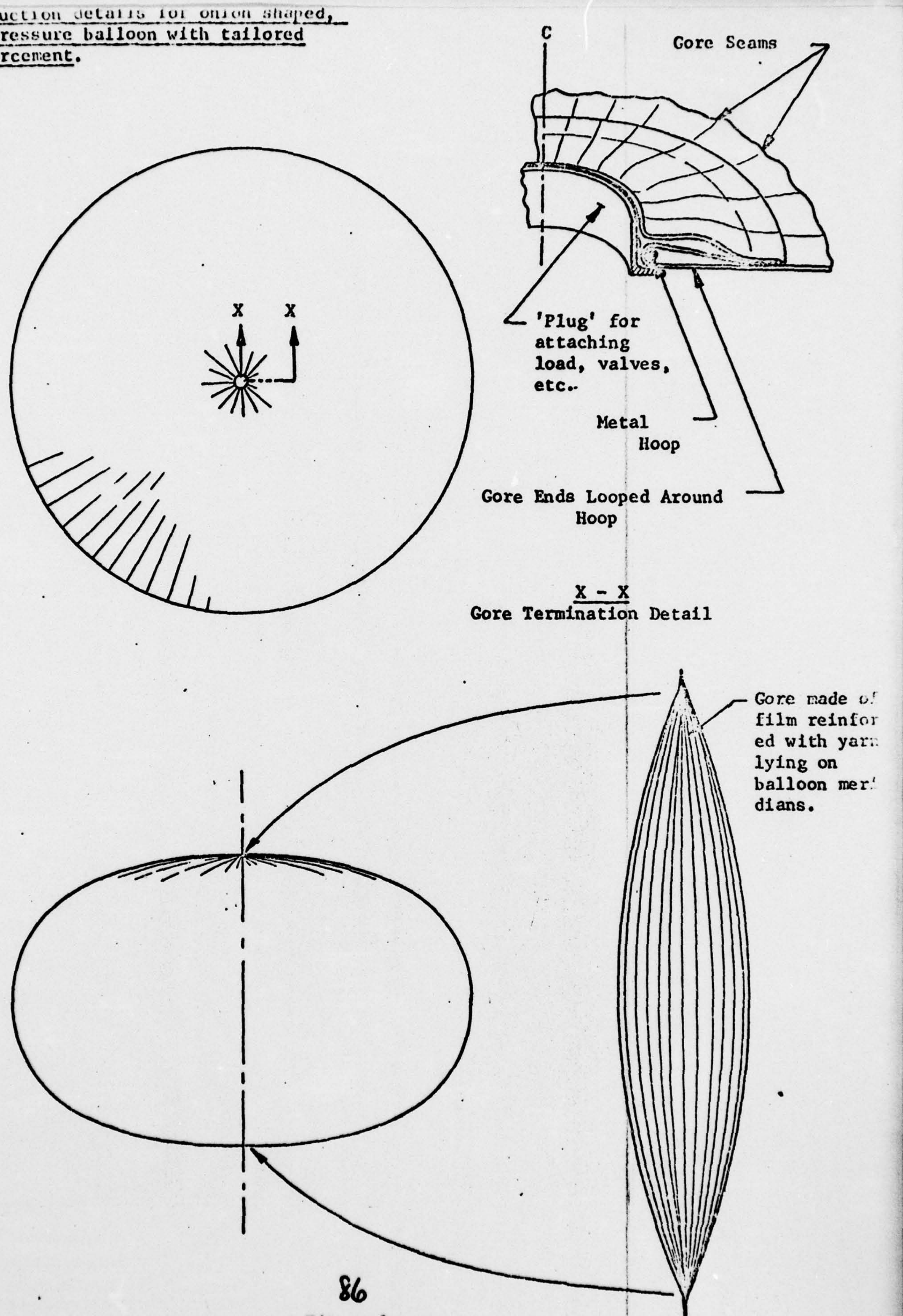
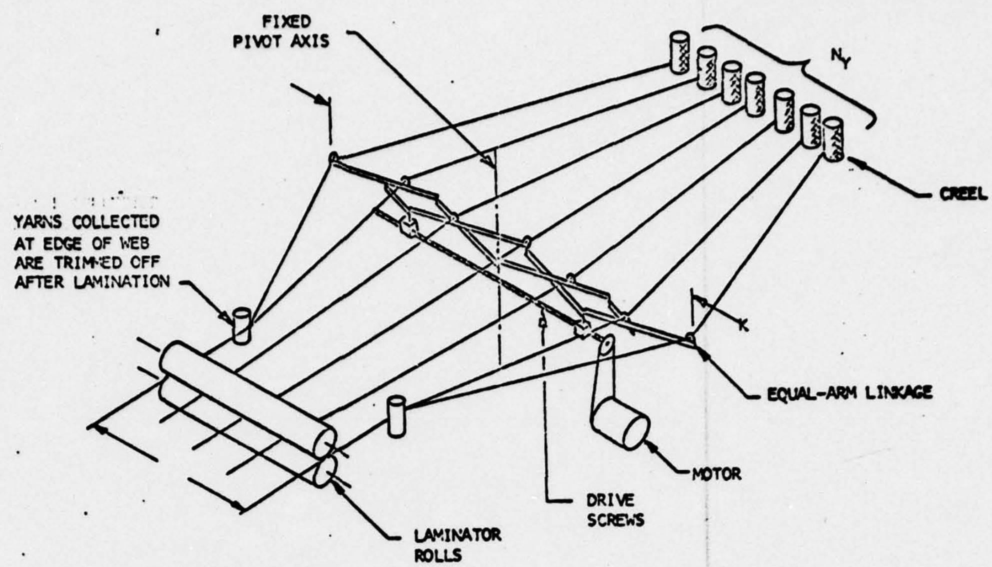
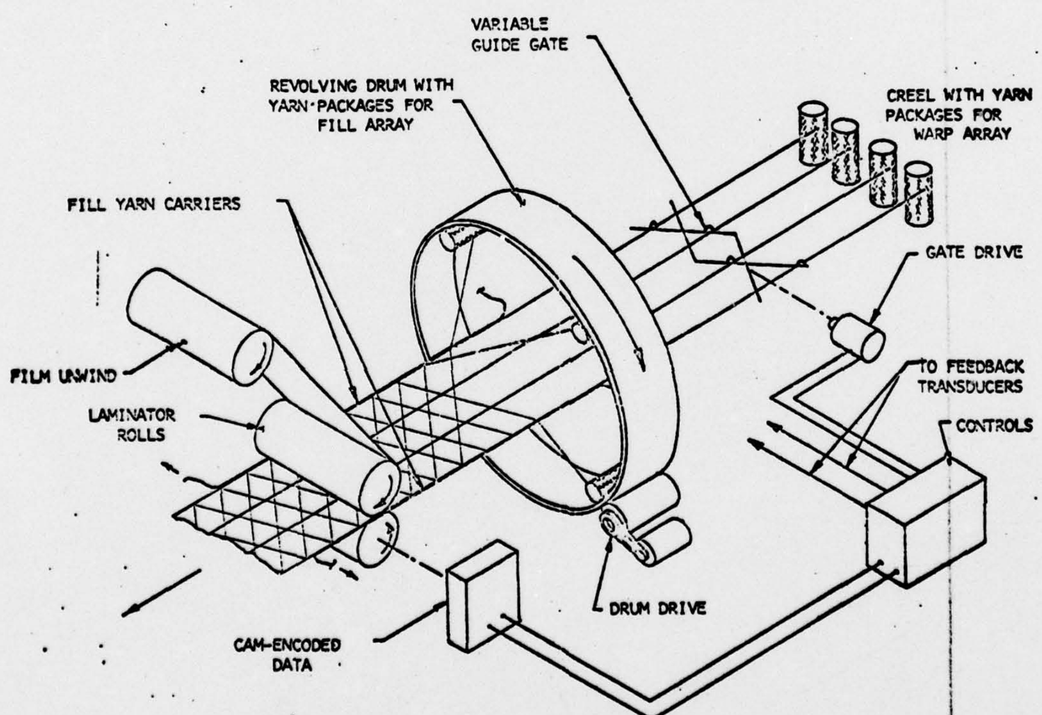


Figure 1


FIXED
PIVOT AXIS
N$_Y$
CREEL
YARNS COLLECTED
AT EDGE OF WEB
ARE TRIMMED OFF
AFTER LAMINATION
K
EQUAL-ARM LINKAGE
MOTOR
DRIVE
SCREWS
LAMINATOR
ROLLS


VARIABLE
GUIDE GATE
REVOLVING DRUM WITH
YARN PACKAGES FOR
FILL ARRAY
CREEL WITH YARN
PACKAGES FOR
WARP ARRAY
FILL YARN CARRIERS
GATE DRIVE
FILM UNWIND
TO FEEDBACK
TRANSDUCERS
LAMINATOR
ROLLS
CONTROLS
DRUM DRIVE
CAM-ENCODED
DATA

DRL
2-20-75

BALLOON FITTING

STATIC LOAD - 5000 lb.

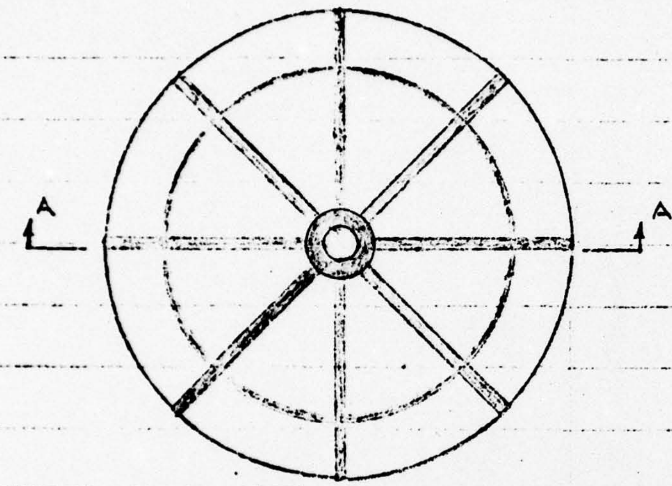
DYNAMIC LOADING

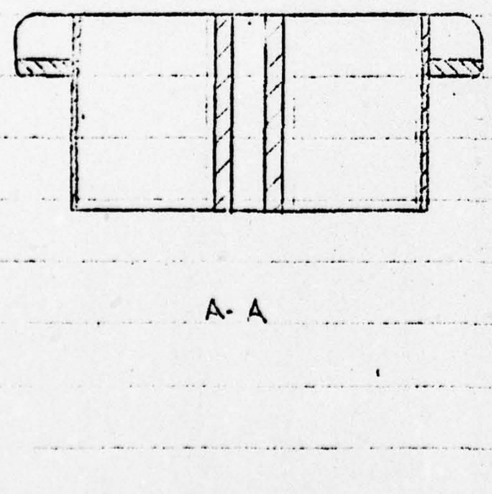
CONDITION → 10,000 lb.

SAFETY FACTOR -

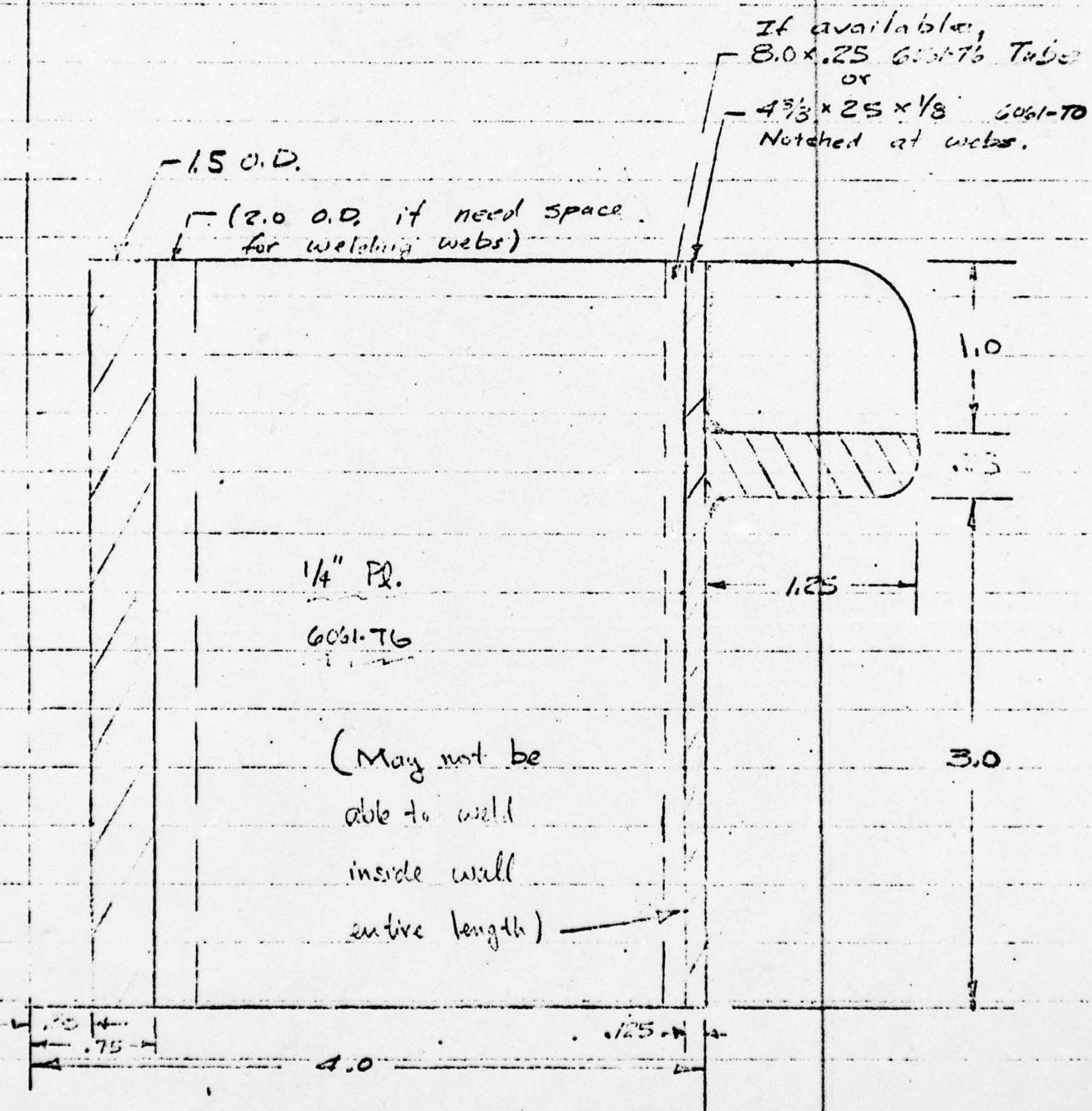
MIN. of 2.0

→ 20,000 lb. ULTIMATE

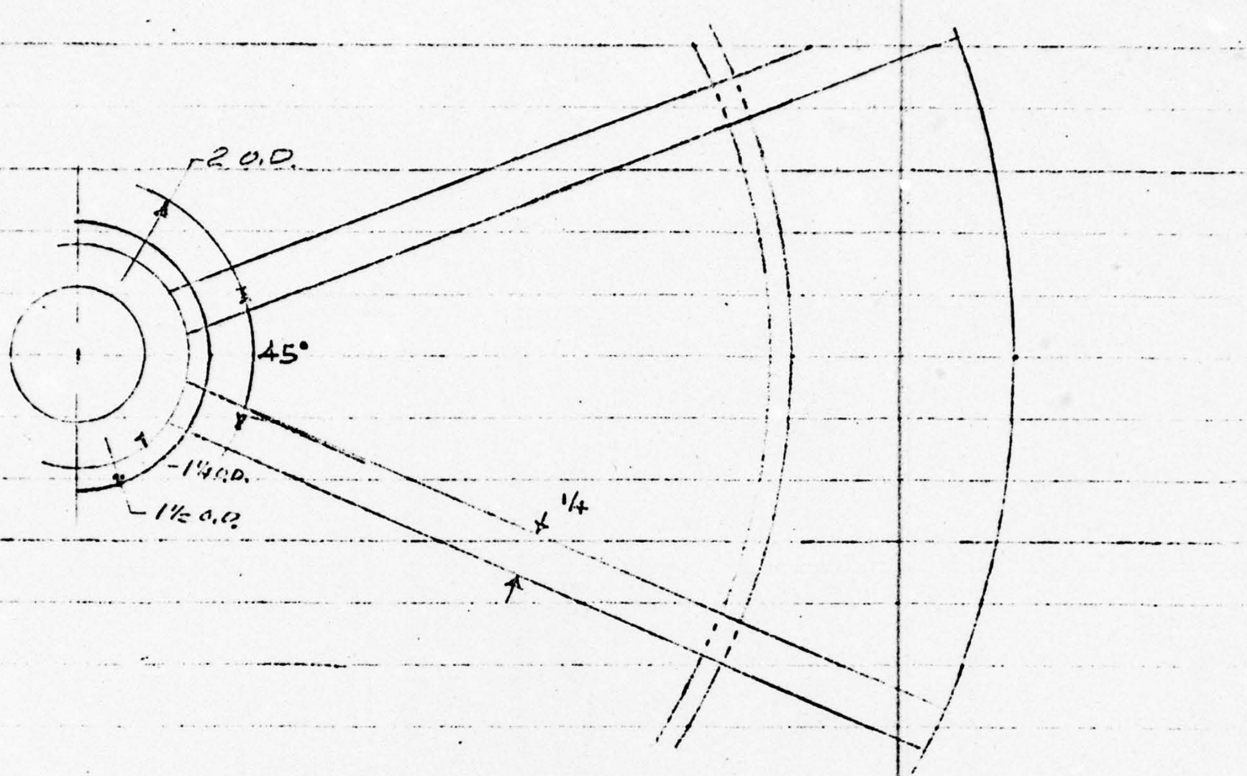




A- A



INTERIOR WEB



WEIGHT (w/o Eyebolt, Nut & Washer, and Welds)

Hub (1.5 O.D.)

$\pi/4\,(1.5^2 - .75^2) \times 4\tfrac{3}{8} \times .101 = 0.59$ lb.

$\{$ 2.0 O.D. — $\pi/4\,(2^2 - .75^2) \times 4\tfrac{3}{8} \times .101 = 1.20$ lb $\}$

Webs — $8 \times \tfrac{1}{4} \times (3\tfrac{7}{8} \times 4\tfrac{3}{8} + 1\tfrac{7}{8} \times 1) \times .101 = 3.04$ [2.96]

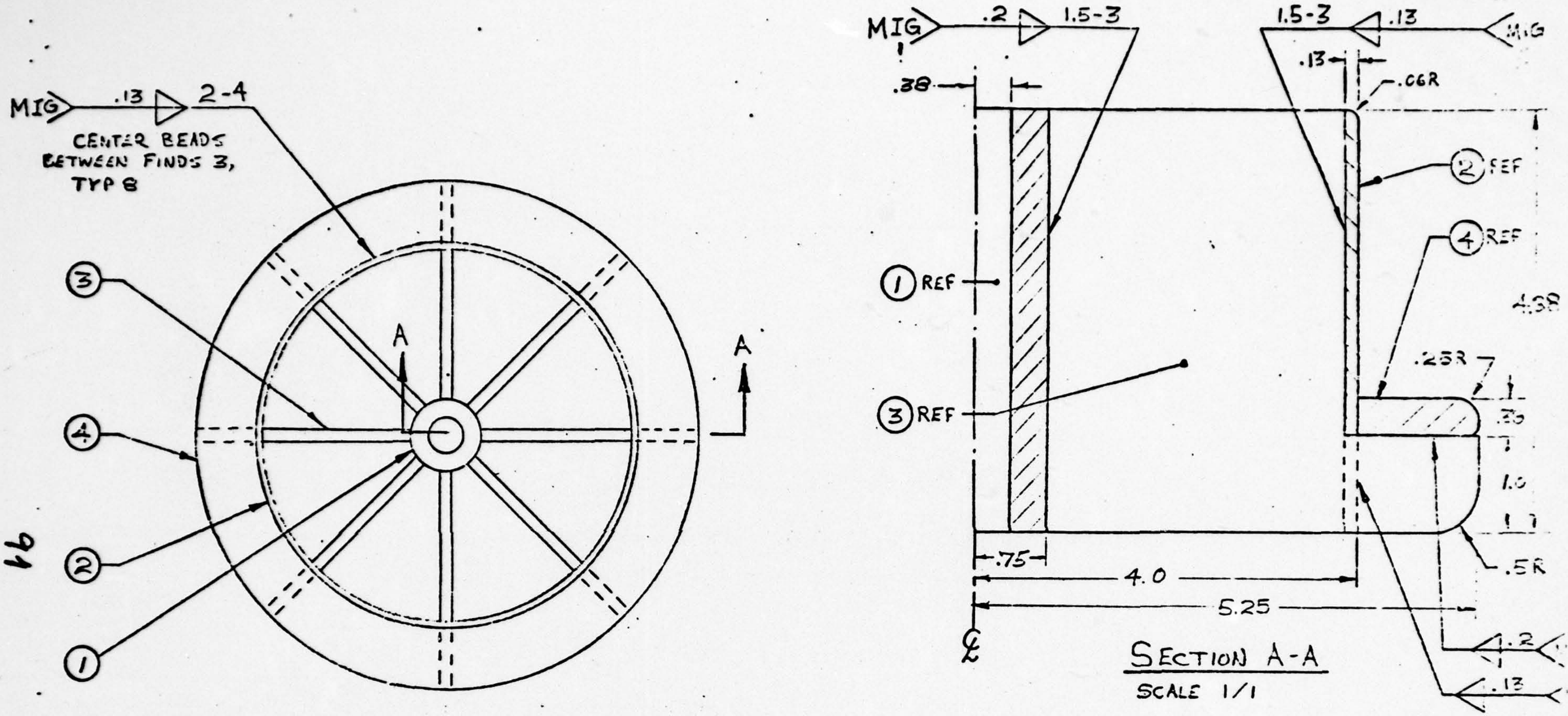
Outside Tube — $\pi\,(4^2 - 3\tfrac{7}{8}^2) \times 4\tfrac{3}{8} \times .101 = 1.37$

[8 × .25 Tube — $\pi\,(4^2 - 3.4^2) \times 4\tfrac{3}{8} \times .101 = 2.67$]

Ring — $\pi\,(5.25^2 - 4^2) \times \tfrac{3}{8} \times .101 = 1.38$

6.38 lb. [7.60]

[illegible] → Total ~ 8-9 lb.



SECTION A-A

SCALE 1/1

REQD	P/N	DESC.	FN
1		RING, 6061-T6 AL ALY	
8		SHEAR PLATE, 6061-T6 AL ALY, .25THK	
1		SLEEVE, 6061-TO AL ALY	
1		TUBE, 6061-T6 AL ALY	

Tolerances:
Fractions ±1/32
Decimals ±.050

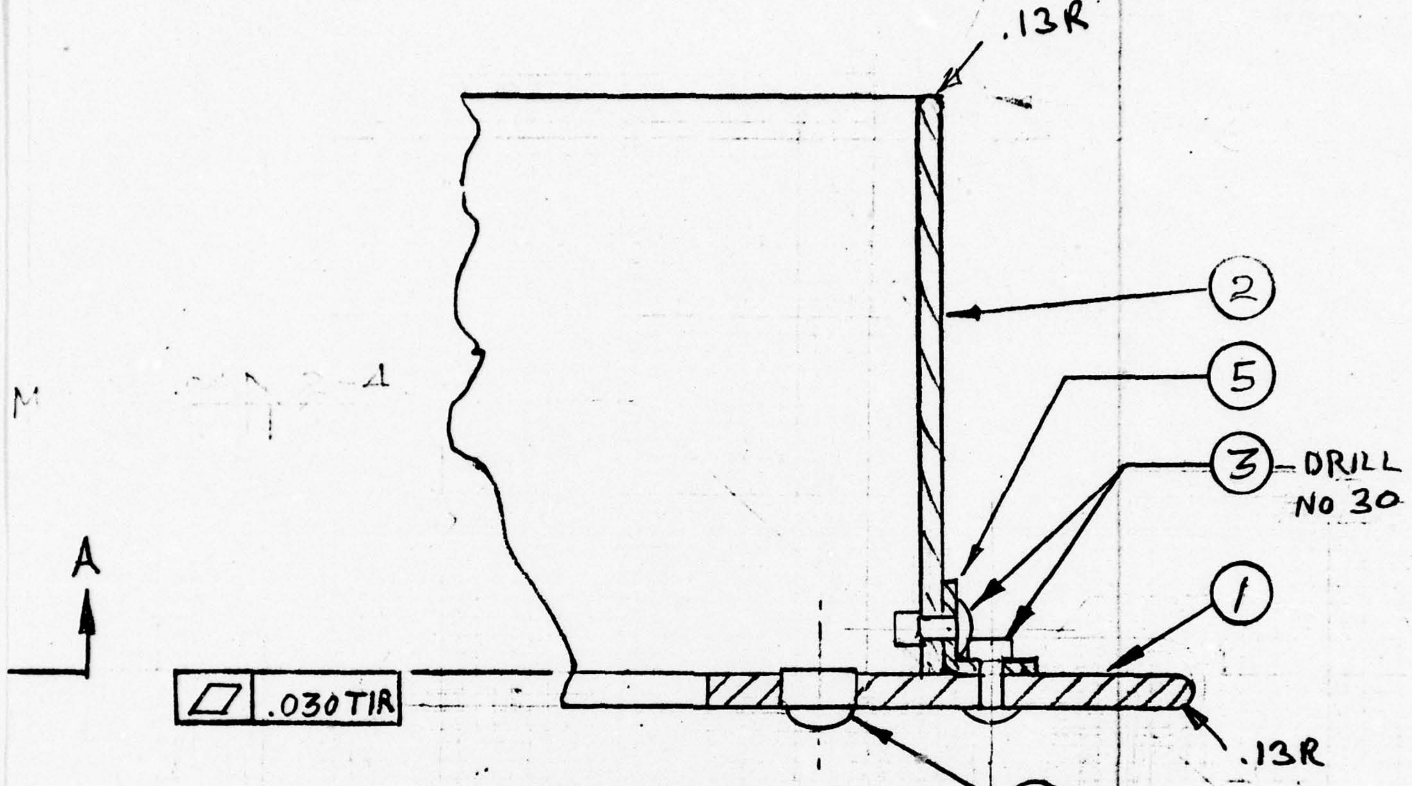
WELDMENT, BALLOON FITTING

Scale 1/2

2 Feb 75

A

NOTES:
WORKMANSHIP PER SHELDAHL STD. 8000001



Section A-A
SCALE 1/1

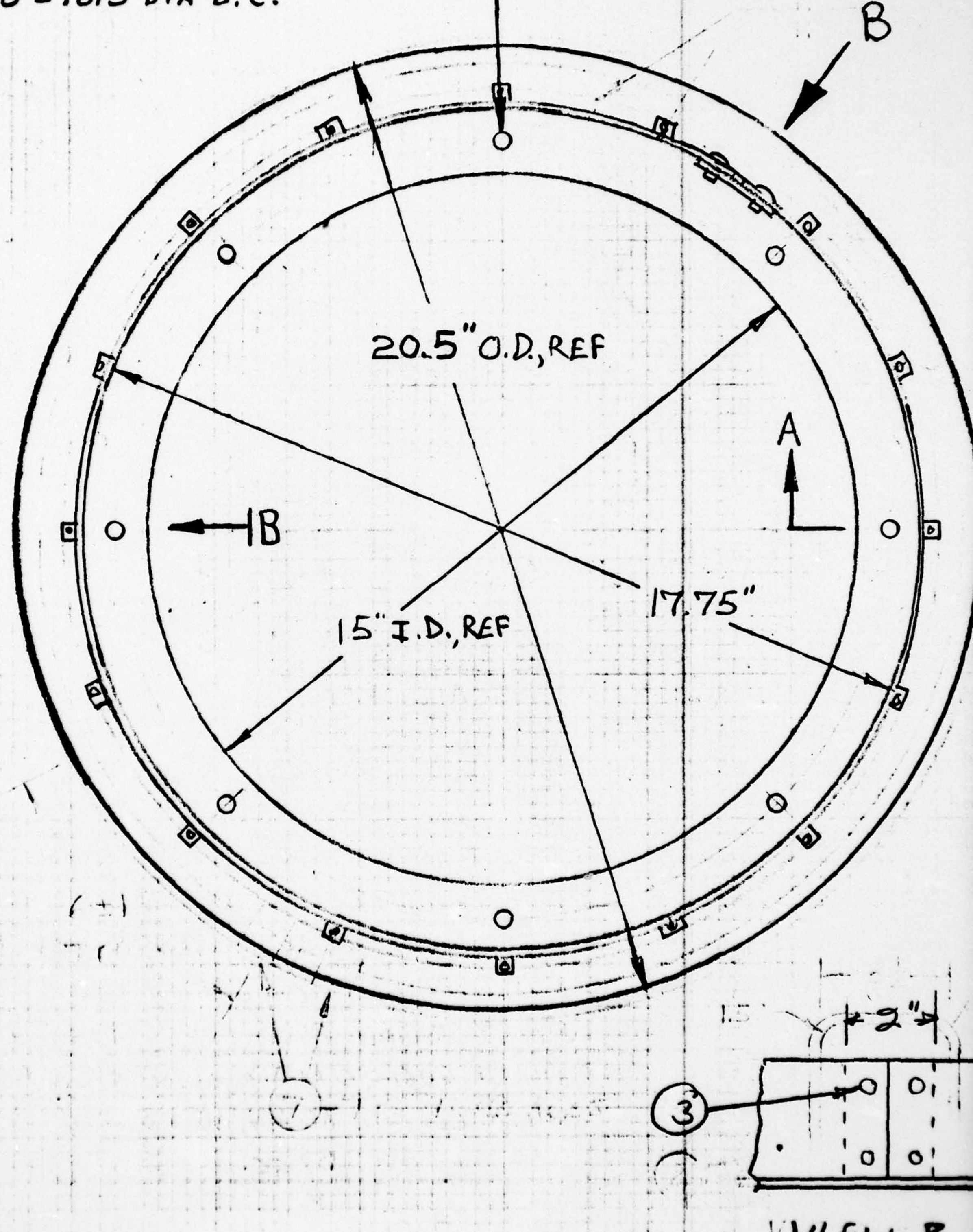
REQD	P/N	DESC.	FIND
~~3'~~	~~D0004[illegible]~~	~~TAPE, FILAMENT 3M898, 3/4 WD~~	~~7~~
~~65"~~	~~———~~	~~TUBING POLYETHYLENE 1/2" O.D.~~	~~6~~
16	———	ANGLE, 6061-T6 AL ALY .5x.5x.06x.5 LG.	5
8	2004198	NUT, SPLINE, 1/4-28 UNF	4
32	———	RIVET BLIND PULL-TYPE .125 D x .36 LG	3
55"	———	SHEET, 6061-T6 AL ALY, .125 x 3.25"	2
1	———	SHEET, 6061-T6 AL ALY, 15" I.D. x 20" O.D. x .188" THK	1

Tolerances
Fractions ± 1/8
Decimals ± .030
17FEB75
JRM.

BALLOON FITTING ASSY, TOP

92 SCALE: 1/3

INSTALL FIND 4 IN .375/.379
HOLE, TYP 8 EQUAL SPACED ON
16.250 ± .015 DIA B.C.

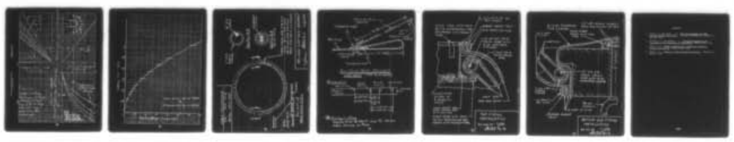


93

AD-A035 227 SHELDAHL INC NORTHFIELD MINN F/G 4/2
POLY-PLUS DEVELOPMENT PROGRAM.(U)
JAN 77 W L SMITH N00014-72-C-0494

UNCLASSIFIED NL

2 OF 2
ADA035227



END
DATE
FILMED
3-77

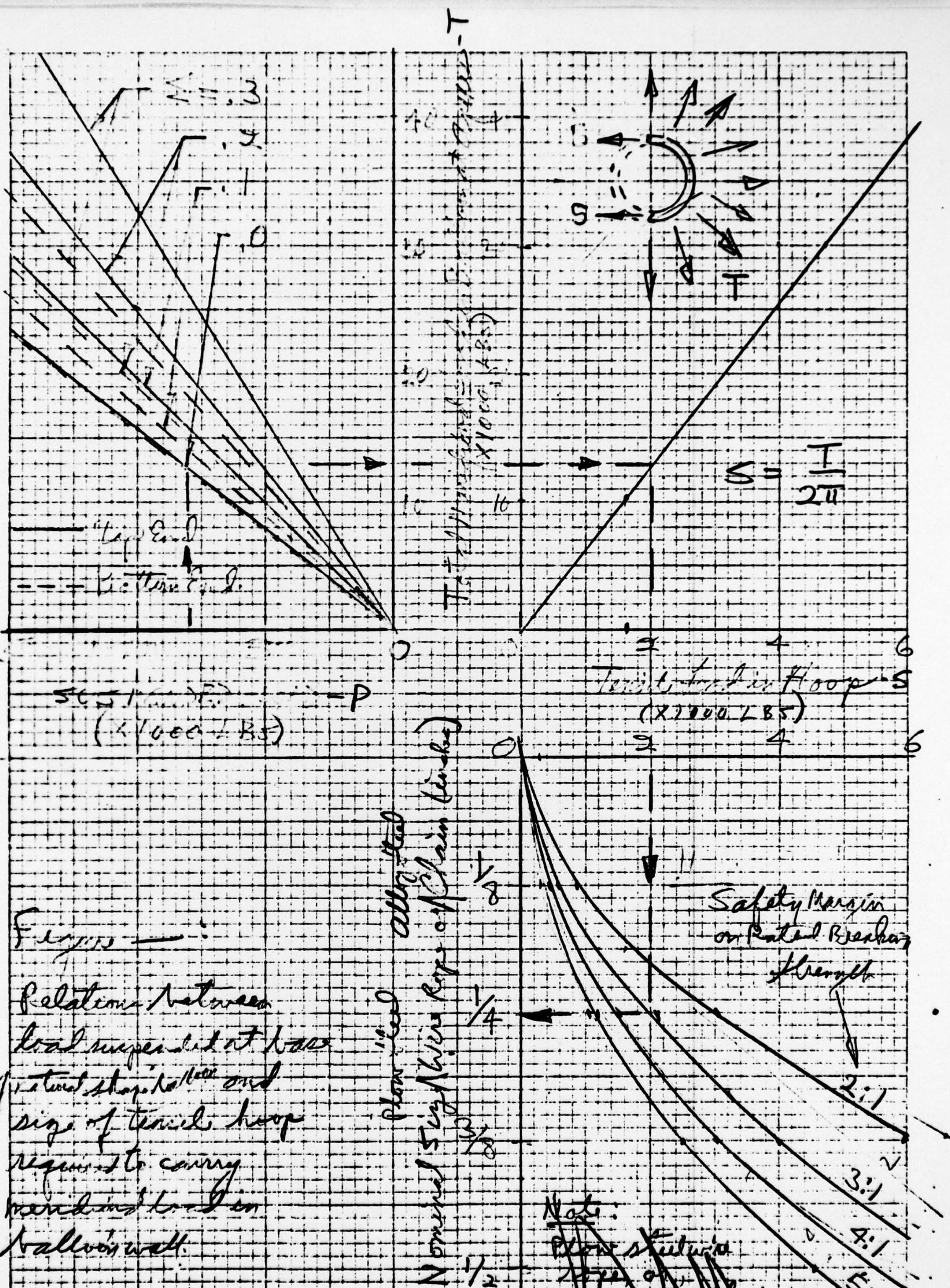
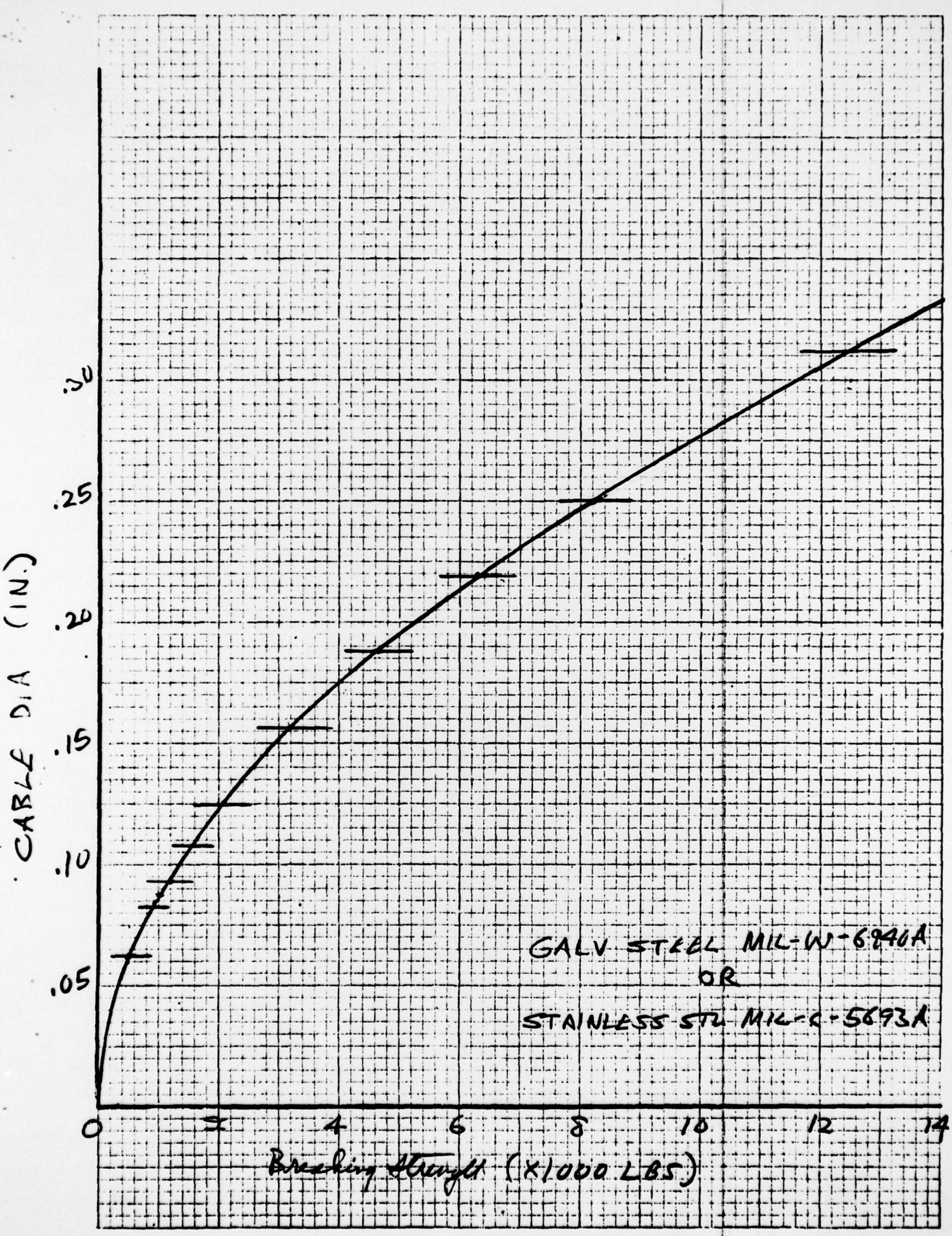
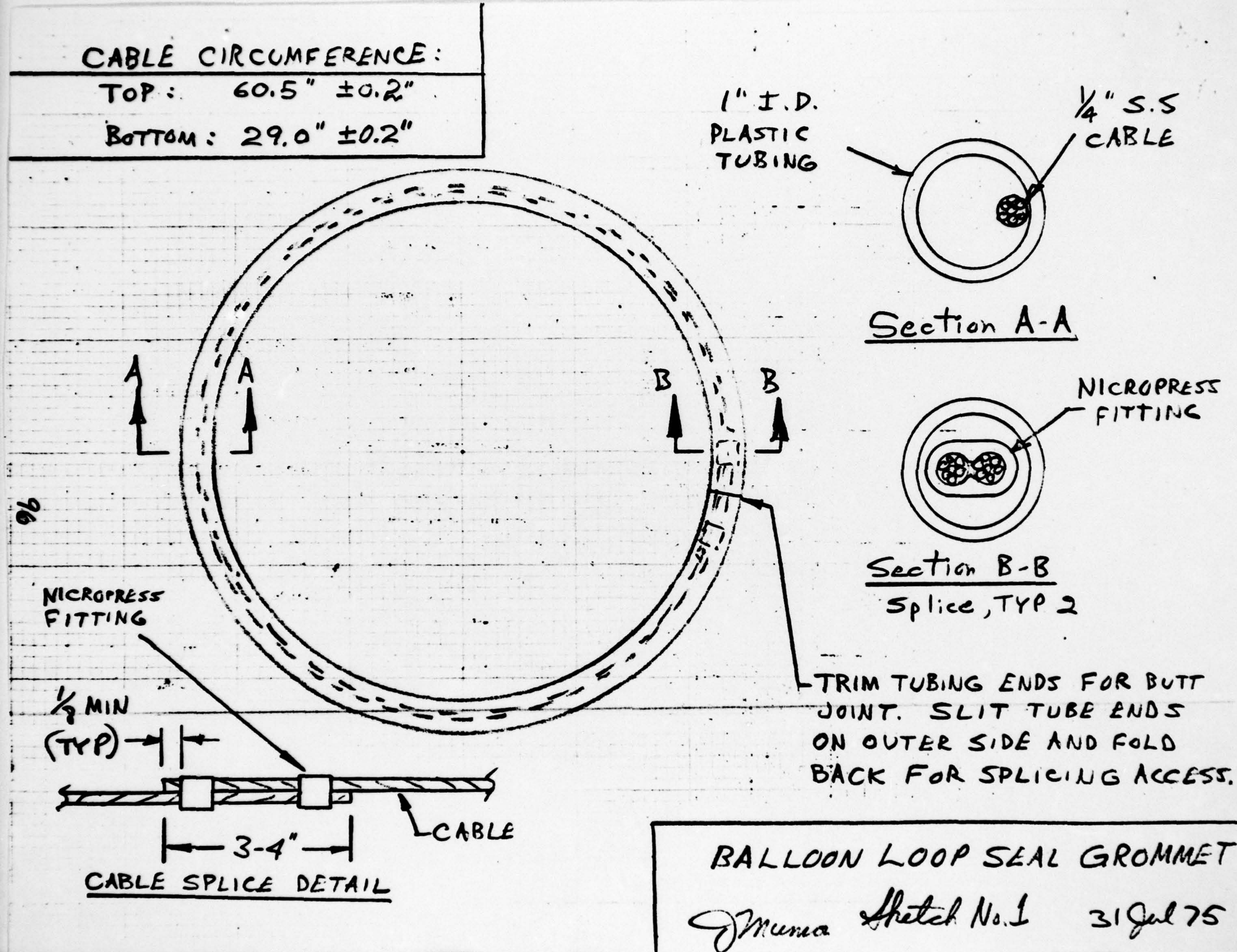
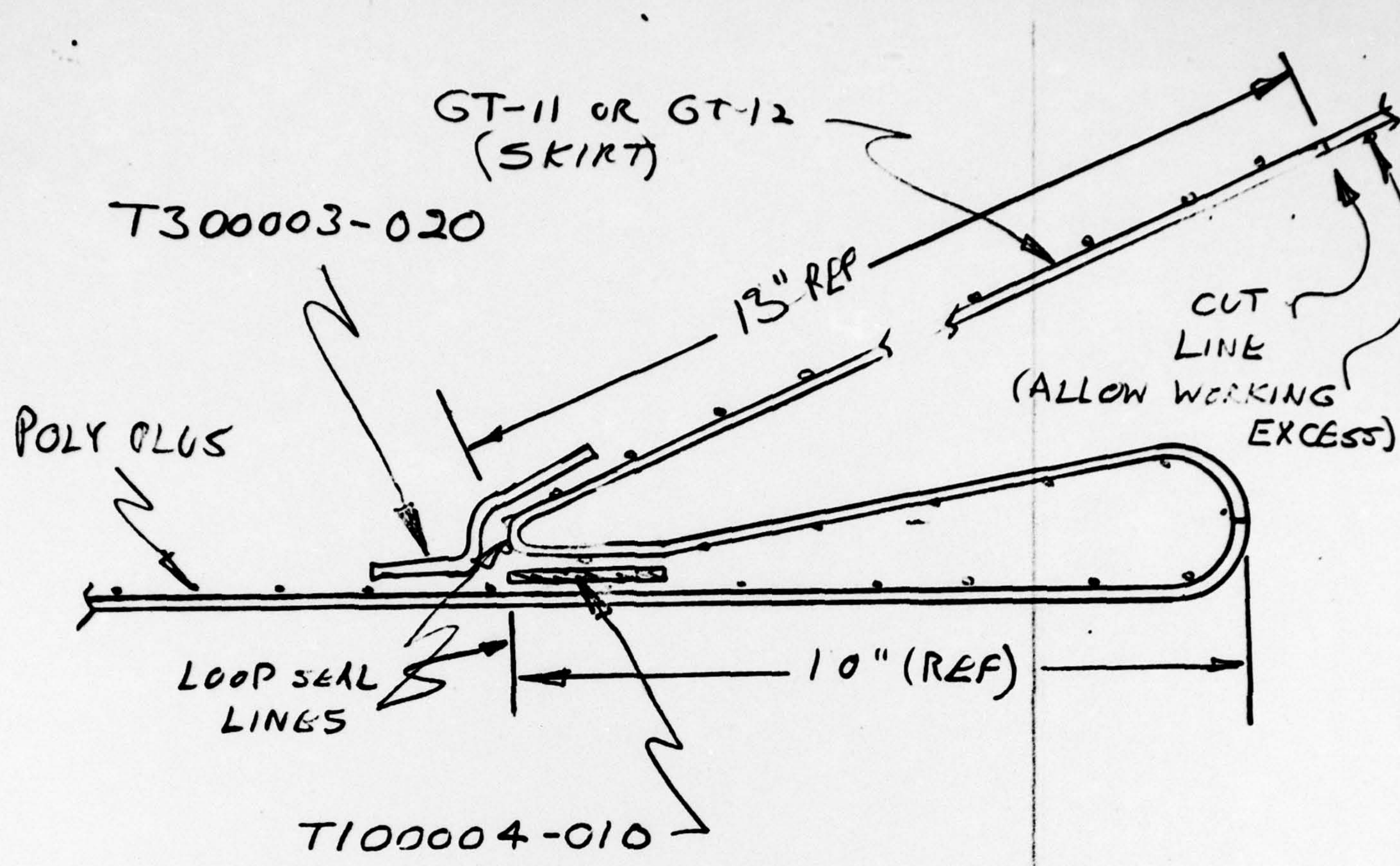


Figure —
Relation between load suspended at base of natural shape balloon and size of tensile hoop required to carry meridional load on balloon wall.

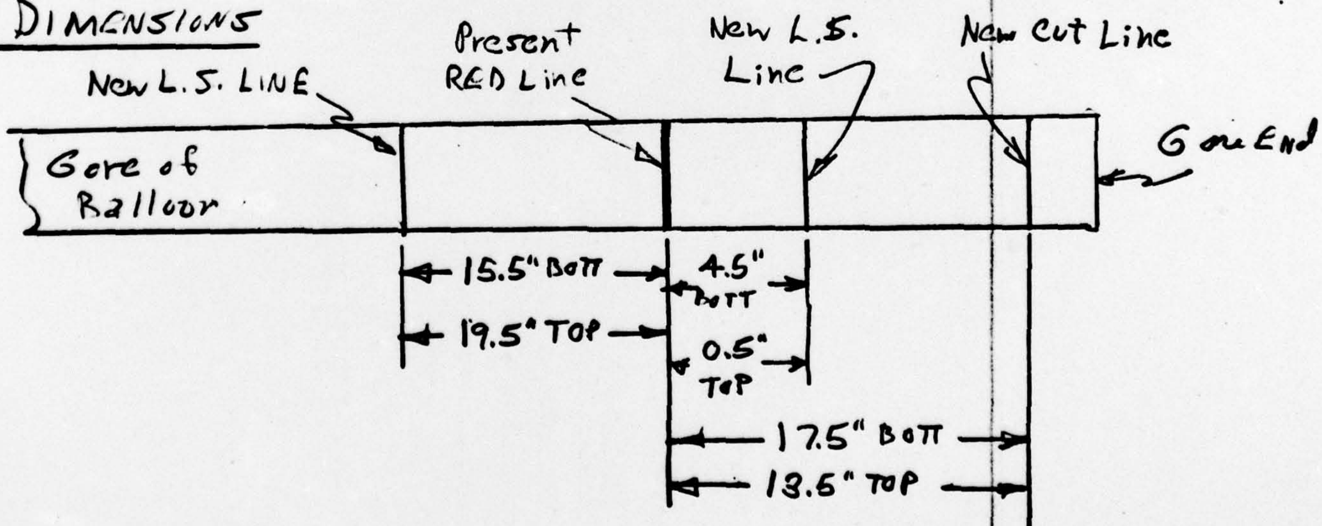

CABLE DIA (IN.)
.05
.10
.15
.20
.25
.30
0
2
4
6
8
10
12
14
~~Breaking Strength~~ (X1000 LBS)
GALV STEEL MIL-W-6940A
OR
STAINLESS STL MIL-C-5693A


CABLE CIRCUMFERENCE:
TOP: 60.5" ±0.2"
BOTTOM: 29.0" ±0.2"
1" I.D. PLASTIC TUBING
1/4" S.S CABLE
Section A-A
NICROPRESS FITTING
Section B-B
Splice, TYP 2
A
A
B
B
TRIM TUBING ENDS FOR BUTT JOINT. SLIT TUBE ENDS ON OUTER SIDE AND FOLD BACK FOR SPLICING ACCESS.
NICROPRESS FITTING
1/8 MIN (TYP)
3-4"
CABLE
CABLE SPLICE DETAIL
BALLOON LOOP SEAL GROMMET
J Munea Sketch No. 1 31 Jul 75



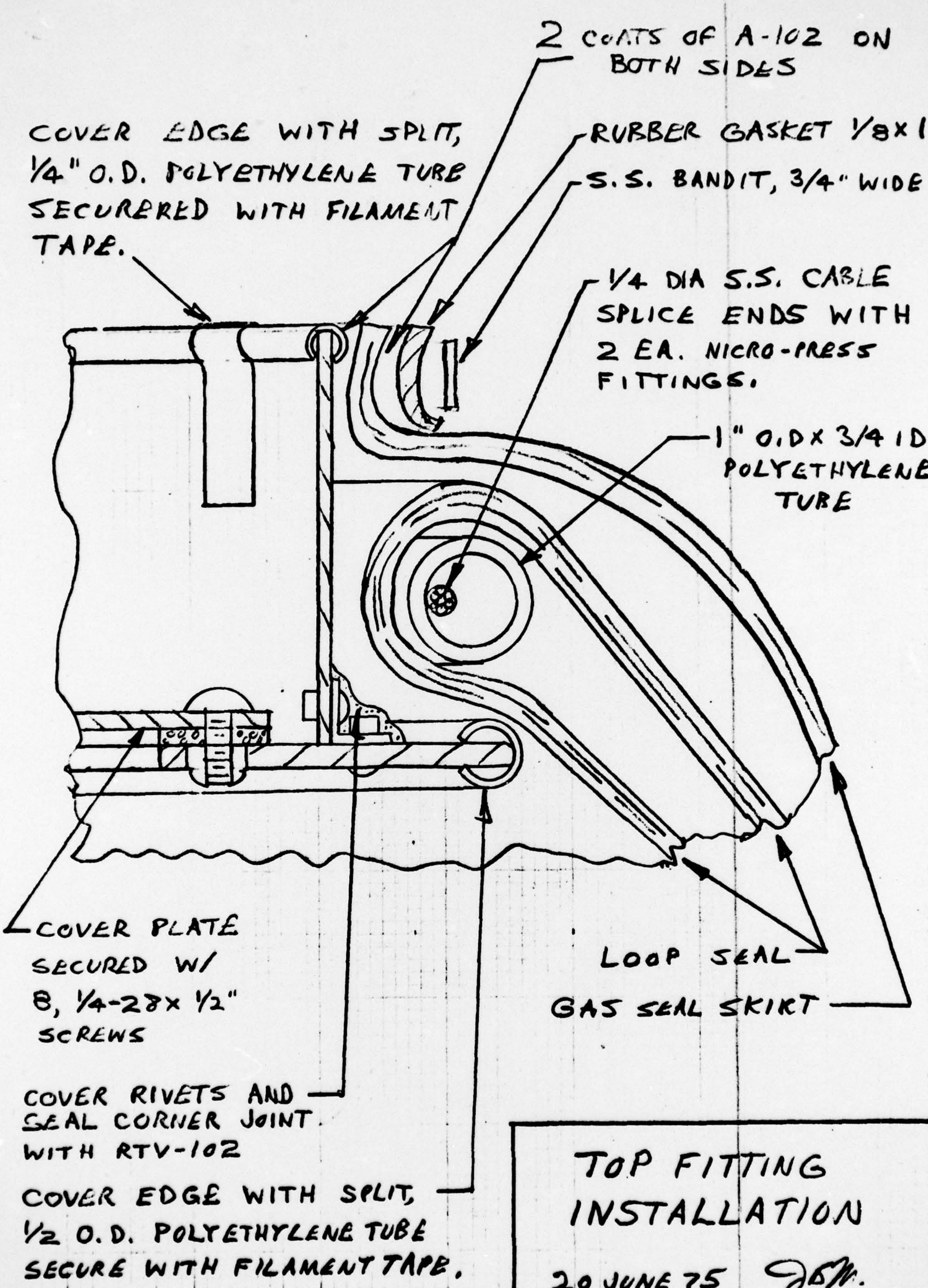
POLY-PLUS TEST BALLOON
LOOP SEAL (TYP BOTH ENDS)

① DIMENSIONS



② Sealing Conditions

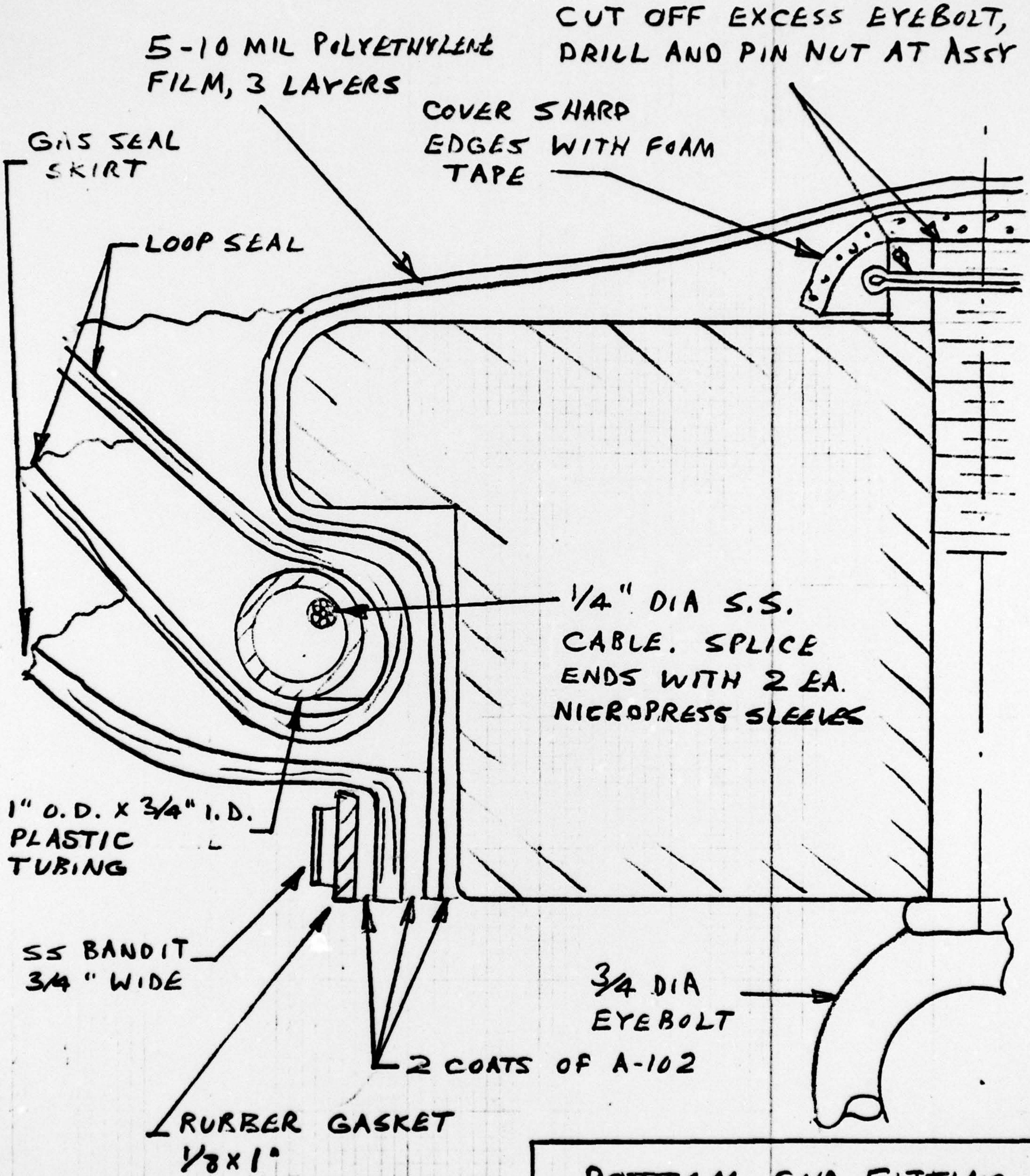
Impulse 15 sec @ 240°F, cool for 20 sec.
Same Pressure as TCOM.



TOP FITTING INSTALLATION

20 JUNE 75 JBM.

Sketch No. 2



BOTTOM END FITTING INSTALLATION

20 JUN 75 JBM

Sketch No. 3

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2. Ellerton, G. C. and Jackson, J. P.: Problems Encountered in the Development of the Stratoscope II Flight System. AFCRL-67-0075, 1967.

3. Munson, J. B.: Design and Manufacture of Composite, Isotensoid, Natural Shape Balloons. AFCRL-70-0498, 1969.

4. Munson, J. B.: Analysis of HAPPE Parachute Test Balloon. Sheldahl Co., SER-0105, 1969.